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Fire Ecology of the Forest Habitat Types of Eastern Idaho and Western Wyoming

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RESEARCH SUMMARY

This report summarizes available information on fire as an ecological factor for forest habitat types occurring in eastern Idaho and western Wyoming. Habitat types are assigned to Fire Groups based primarily on fire's role in forest succession.

For each Fire Group, the authors discuss (1) the relationships of major tree species to fire, (2) forest fuels, (3) the natural role of fire, (4) fire and forest succession, and (5) fire management considerations.

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INTRODUCTION

This report summarizes the available fire ecology and management information relating to the forest habitat types of eastern Idaho and western Wyoming, west of the crest of the Wind River Mountains. Fire ecology of forest habitat types in the Bridger-Teton, Caribou, and Targhee National Forests are described, with the exception of the western portion of the Targhee's Dubois District. The fire ecology of central Idaho forests including the western Targhee National Forest is described in Crane and Fischer (1986). The information in the present publication also applies to the forested portions of Yellowstone and Grand Teton National Parks. The primary purpose of this report is to promote the understanding of fire's role in forest ecosystems, particularly its role in forest succession. Several companion documents may be of interest to managers in western Wyoming and southeastern Idaho. The fire ecology of Wyoming forests from the crest of the Wind River Range eastward are described in Crane and others (in preparation). Utah forest and woodland fire ecology is discussed in Bradley and others (1992). The fire ecology of eastern Montana forests to the north is described by Fischer and Clayton (1983).

Habitat types and community types described by Steele and others (1983) and Mueggler (1988) are assigned to eight "Fire Groups" based on the response of dominant tree species to fire, potential frequency of fire, and similarity in postfire succession.

The successional path taken by any given forest site following fire depends on many variables. The preburn vegetation, size and severity of the fire, topography, climate and soil, and chance all contribute to the process. Thus, a single habitat type may be a member of more than one Fire Group. The groups defined in this report are offered only as a general guide. The individual land manager must evaluate conditions on a site-by-site basis to determine the most likely results of fire.

Format

This report is patterned after "Fire Ecology of Montana Forest Habitat Types East of the Continental Divide" (Fischer and Clayton 1983). The major topics presented in this report are organized into sections, described below.

Relationship of Major Tree Species to Fire—This section discusses each principal tree species with regard to its resistance or susceptibility to fire and its role as a successional component of forest communities. Particular attention is given to special adaptations to fire, such as corky bark, serotinous cones, or seeds that require mineral soil for germination.

Undergrowth Response to Fire—This section summarizes the effect of fire on the response of important grass, forb, and shrub species associated with the major conifer species. Particular attention is given to fire-adaptive traits or survival strategies that determine whether fire generally increases or decreases species cover in the immediate postfire period.

Wildlife Response to Fire—This section briefly summarizes the general effects of fire on common mammals, reptiles, amphibians, and birds occurring in western Wyoming or southeastern Idaho. Fire response of wildlife is largely inferred from expected changes in habitat as a result of fire.

Fire Use Considerations—This section summarizes cautions that apply to the use of fire for resource management purposes. Emphasis is on

effective use of fire, site protection, minimizing damage to residual stand, and wildlife habitat protection.

Fire Groups and Their Relationship to Cover Types—The Fire Groups are defined with reference to "Forest Habitat Types of Eastern Idaho-Western Wyoming" (Steele and others 1983) and "Aspen Community Types of the Intermountain Region" (Mueggler 1988). The coniferous forest habitat types assigned to eastern Idaho and western Wyoming Fire Groups are listed in appendix A and summarized in table 1.

Table 1—Summary of eastern Idaho and western Wyoming habitat type Fire Groups (see appendix A for formal listing of habitat types)

Habitat type	Habitat type	Habitat type
FIRE GROUP ZERO	POTR/SYOR/THFE	ABLA/PERA
Misc. special habitats	POTR/SYOR/TALL FORB	ABLA/PHMA
	POTR/TALL FORB	ABLA/SPBE
FIRE GROUP ONE	POTR/THFE	ABLA/SYAL
PIFL/CELE	POTR/WYAM	ABLA/THOC
PIFL/FEID-FEID	POTR-ABLA/AMAL	ABLA/VAGL-PAMY
PIFL/HEKI	POTR-ABLA/PERA	ABLA/VAGL-VASC
PIFL/JUCO	POTR-ABLA/SHCA	ABLA/VAGL-VAGL
	POTR-ABLA/TALL FORB	ABLA/VASC-CARU
FIRE GROUP TWO	POTR-ABLA/SYOR	ABLA/VASC-VASC
PSME/ARCO-ASMI	POTR-ABLA/SYOR/THFE	ABLA/XETE-VAGL
PSME/ARCO-ARCO	POTR-PICO/CAGE	ABLA/XETE-VASC
PSME/BERE-SYOR	POTR-PICO/SYOR	PIEN/ARCO
PSME/CELE	POTR-PSME/AMAL	PIEN/HYRE
PSME/FEID-FEID	POTR-PSME/CARU	PIEN/JUCO
PSME/JUCO	POTR-PSME/SYOR	
PSME/SYOR		**FIRE GROUP SEVEN**
	FIRE GROUP FIVE	ABLA/ACRU
FIRE GROUP THREE	PICO/ARCO	ABLA/CACA-LEGL
PSME/ACGL-PAMY	PICO/CAGE	ABLA/CACA-VACA
PSME/BERE-CAGE	PICO/CARO	ABLA/CACA-CACA
PSME/BERE-JUCO	PICO/CARU	ABLA/MEFE-MEFE
PSME/BERE-BERE	PICO/JUCO	ABLA/STAM-STAM
PSME/CARU-PAMY	PICO/LIBO	PIEN/CALE
PSME/CARU-CARU	PICO/SHCA	PIEN/CADI
PSME/OSCH	PICO/SPBE	PIEN/EQAR
PSME/PHMA-PAMY	PICO/VAGL	PIEN/GATR
PSME/PHMA-PSME	PICO/VASC	PIEN/LIBO
PSME/PHMO		PIEN/PHMA
PSME/SPBE-CARU	**FIRE GROUP SIX**	
PSME/SPBE-SPBE	ABLA/ACGL-PAMY	**FIRE GROUP EIGHT**
PSME/SYAL-SYAL	ABLA/ARCO-ASMI	ABLA/LUHI-VASC
PSME/VAGL-VAGL	ABLA/ARCO-PIEN	ABLA/RIMO-PIAL
	ABLA/ARCO-SHCA	ABLA/RIMO-RIMO
FIRE GROUP FOUR	ABLA/ARCO-ARCO	ABLA/VASC-PIAL
POTR/AMAL-SYOR/CARU	ABLA/ARLA	PIEN/RIMO
POTR/AMAL-SYOR/TALL FORB	ABLA/BERE-CAGE	PIEN/VASC
POTR/AMAL/TALL FORB	ABLA/BERE-BERE	PIAL/CAGE
POTR/AMAL/THFE	ABLA/CAGE-CAGE	PIAL/CARO-PICO
POTR/ARTR	ABLA/CARO	PIAL/CARO-CARO
POTR/ASMI	ABLA/CARU-PAMY	PIAL/FEID
POTR/BRCA	ABLA/CARU-CARU	PIAL/JUCO-SHCA
POTR/CARO	ABLA/JUCO	PIAL/JUCO-JUCO
POTR/EQAR	ABLA/LIBO-VASC	PIAL/VASC
POTR/POPR	ABLA/LIBO-LIBO	
POTR/SHCA	ABLA/OSCH-PAMY	
POTR/SYOR/CARU	ABLA/OSCH-OSCH	

Habitat types are designated in the standard format of "series/type-phase," in which "series" designates the potential climax dominant tree, "type" designates a definitive undergrowth species, and "phase" provides a further subdivision where needed.

Forest cover types have been described for Yellowstone National Park (U.S. Department of the Interior 1991). Unlike habitat types, cover types are not based on potential vegetation, but on the vegetative cover presently observed on a site. As a result, cover types that designate seral vegetative stages may be in more than one fire group. For example, Yellowstone cover type 40 designates "... recently disturbed wet areas or high-elevation cirques where reproduction is clearly dominated by Englemann spruce and subalpine fir." Stands in this cover type may fall in Fire Groups Seven or Eight, which include subalpine habitat types found in very moist or timberline sites, respectively. Managers should use care when relating the cover type system to the Fire Group system described in this document. Lodgepole pine cover types (30-34) correlate well with Fire Group Five: Persistent Lodgepole Pine. The available fuel information for the cover types has been incorporated in the description of Group Five.

Vegetation—Following the list of habitat types that comprise each Fire Group, we describe the characteristic overstory and undergrowth vegetation for that Group. Climax and seral tree species are identified.

Forest Fuels—The fuels likely to occur in each Fire Group are characterized in this section. Where data are available, representative downed and dead woody fuel loadings are reported. To date, the most complete data in the region are from Montana. Summaries from Montana fuel studies are provided as examples when local data have not been published. Live and standing dead fuels are discussed where they contribute significantly to fire hazard, and typical fire behavior in the Fire Group is described.

Role of Fire—Information on the important trees and forest fuel characteristics is integrated with the results of fire history studies to describe the historical (presettlement period, generally prior to 1900) role of fire in shaping the vegetative composition of a particular Fire Group.

Fire severity is a qualitative measure used to describe the biological impacts of fire. It reflects the mortality of flora and fauna and the loss of organic material. Both upward and downward heat flux affect mortality. Upward heat flux is usually expressed by terms like fireline intensity and flame length. It is largely responsible for aboveground plant mortality. Downward heat flux is related to fuel consumption and exposure of mineral soil (Brown and DeByle 1989). The downward heat flux affects the ability of shrubs to resprout or seeds dormant in soil to become active. Ryan and Noste (1985) have summarized easily observed soil and fuel charcteristics that can be used to classify fire severity in timber, shrub, or grass fuels (table 2).

For the purpose of this report three levels of fire severity are defined: low severity or cool fire, moderate fire, and high severity or severe fire. A *low severity or cool fire* is one that has minimal impact on the site. It burns in surface fuels consuming only the litter, herbaceous fuels, and foliage and small twigs on woody undergrowth. Very little heat travels downward through the duff. A *moderate fire* burns in surface fuels also but may involve a tree understory as well. It consumes litter, upper duff, understory plants, and foliage on understory trees. Individual and groups of overstory trees may torch out if fuel ladders exist. A *severe fire* is one that burns through the overstory and consumes large woody surface fuels, removes the entire duff layer, or both, over much of the area. Heat from the fire impacts the upper soil layer and often consumes the incorporated soil organic matter.

Forest Succession—For each Fire Group, successional pathway flow charts represent a synthesis of both knowledge and speculation about the effects of fire at several points in the life history of a stand. They illustrate the many possible influences fires of varying severities have on stands of differing ages, densities, and species composition. The flow charts follow the method suggested by Kessell and Fischer (1981).

How trees respond to fire often depends on their size. Tree size classes used in our flow charts are (Society of American Foresters 1958): *Saplings*—2 to 4 inches in diameter at breast height (d.b.h.); *small poles*—4 to 8 inches, d.b.h; *large poles*—8 to 12 inches, d.b.h.

The tree species names are symbolized in order to simplify the diagrams and flow charts. The symbols are defined as follows:

Abies lasiocarpa, subalpine fir (ABLA)
Juniperus scopulorum, Rocky Mountain juniper (JUSC)
Picea engelmannii, Engelmann spruce (PIEN)
Picea pungens, blue spruce (PIPU)
Pinus albicaulis, whitebark pine (PIAL)
Pinus contorta, lodgepole pine (PICO)
Pinus flexilis, limber pine (PIFL)
Populus tremuloides, quaking aspen (POTR)
Pseudotsuga menziesii, Douglas-fir (PSME)

Fire Management Considerations—This section discusses how the preceding information for each Fire Group can be used to develop fire management plans that support land and resource management objectives. Suggestions given are offered as an aid

Table 2—Visual character of ground char from observation of depth of burn[1] (Ryan and Noste 1985)

Ground char class	Site		
	Timber/slash	Shrubfields	Grasslands
Unburned	The fire did not burn on the forest floor. Some damage may occur to vegetation due to radiated or convected heat from adjacent areas. Ten to 20 percent of the area within slash burns is commonly unburned.[2] Percentage of unburned area varies widely within burns in natural fuels.	See timber/slash	See timber/slash
Light ground char	Leaf litter is charred or consumed. Upper duff may be charred, but the duff layer is not altered over the entire depth. The surface generally appears black immediately after the fire. Woody debris is partially burned. Some small twigs and much of the branch wood remain. Logs are scorched or blackened but not charred. Crumbled, rotten wood is scorched to partially burned. Light ground char commonly makes up 0-100 percent of burned areas with natural fuels and 45-75 percent of slash areas.	Leaf litter is charred or consumed, and some leaf structure is still discernible. The surface is predominantly black, although some gray ash may be present immediately after the fire. Gray ash soon becomes inconspicuous. Charring may extend slightly into soil surface where leaf litter is sparse, but the mineral soil is not otherwise altered. Some leaves and small twigs remain on the plants. Burns are irregular and spotty. Less than 60 percent of the brush canopy is commonly consumed.	Litter is charred or consumed, but some plant parts are still discernible. Charring may extend slightly into the soil surface, but the mineral soil is not otherwise altered. Some plant parts may still be standing. Bases of plants are not deeply burned and are still recognizable. Surface is predominantly black immediately after the burn, but this soon becomes inconspicuous. Burns may be spotty to uniform, depending on the continuity of the grass.
Moderate ground char	Litter is consumed.[3] Duff is deeply charred or consumed but the underlying mineral soil is not visibly altered. Light-colored ash prevails immediately after the fire. Woody debris is largely consumed. Some branch wood is present, but no foliage or twigs remain. Logs are deeply charred. Moderate ground char commonly occurs on 0-100 percent of natural burned areas and 10-75 percent on slash burns.	Surface leaf litter is consumed. Some charred litter may remain but is sparse. Charring extends up to 0.5 inch into mineral soil but does not otherwise alter the mineral soil. Gray or white ash is conspicuous immediately after the burn, but this quickly disappears. Some charred stems remain on the plants, and these are generally greater than 0.25-0.50 inch in diameter.	Litter is consumed, and the surface is covered with gray or white ash immediately after the burn. Ash soon disappears, leaving bare mineral soil. Charring extends slightly into mineral soil, but the plant parts are no longer discernible, no plant parts standing, and the bases of plants are burned to ground level. Plant bases are obscured in the ash immediately after burning.

(con.)

Table 2 (Con.)

Ground char class	Site: Timber/slash	Shrubfields	Grasslands
Moderate ground char	Trees with lateral roots in the duff are often left on pedestals or topple. Burned-out stump holes are common.	Burns are more uniform than in previous classes. Between 40 and 80 percent of the brush canopy is commonly consumed.	Burns tend to be uniform. Moderate ground char is generally limited to backing fires and fires burning during dry conditions.
Deep ground char	Litter and duff are completely consumed, and the top layer of mineral soil is visibly altered, often reddish. Structure of the surface soil may be altered. Below the colored zone 1 inch or more of the mineral soil is blackened from organic material that has been charred or deposited by heat conducted downward. Twigs and small branches are completely consumed. Few large branches may remain, but those are deeply charred. Sound logs are deeply charred, and rotten logs are completely consumed. Deep ground char occurs in scattered patches under slash concentrations or where logs or stumps produced prolonged, intense heat. Deep ground char generally covers less than 10 percent of natural and slash areas. One extreme case of 31 percent was reported in a slash burn. In extreme cases, clinkers or fused soil may be present. These are generally restricted to areas where slash was piled.	Leaf litter is completely consumed, leaving a fluffy white ash surface. All organic matter is consumed in the mineral soil to a depth of 0.5-1.0 inch. This is underlain by a zone of black organic material. Colloidal structure of the surface mineral soil may be altered. Large branches with main stems are burned, and only stubs greater than 0.5 inch in diameter remain.	Deep ground char is uncommon due to short burnout time of grasses. Surface consists of fluffy white ash immediately after the burn. This soon disappears, leaving bare mineral soil. Charring extends up to 0.5 inch into soil. Soil structure is slightly altered (for consistency with other fuel types, no citations specifically mention soil alteration). Deep ground char is generally limited to situations where heavy loadings on mesic sites have burned under dry conditions and low wind.

[1]Visual characteristics were developed from the following literature sources and combined for consistency: Bever 1954; Tarrant 1956; Dyrness and Youngberg 1957; Bentley and Fenner 1958; Daubenmire 1968; Morris 1970; Ralston and Hatchell 1971; Vogl 1974; and Wells and others 1979.

[2]The area coverage estimates for each of the ground char classes are ranges encountered in the literature and experienced by the authors. Obviously, any combination of depth of char classes is possible. The inclusion of these ranges points out the variability that may be encountered within a given fuel situation.

[3]Some late-season fires have been observed to spread by glowing combustion in the duff, leaving the charred remains of the litter on top of the mineral soil and ash. This should not be confused with light ground char because temperature measurements indicate a considerable heat pulse is received by the mineral soil.

to decisionmaking, but for specific situations managers must rely on their experience to determine how to use information presented in this document.

Nomenclature

Common names of trees and scientific names of undergrowth plants are used throughout the text of the report. Corresponding scientific plant names and common names used in the text are listed in appendix B. Nomenclature generally follows "Flora of the Pacific Northwest" (Hitchcock and Cronquist 1973) except as otherwise noted. A major exception is the nomenclature for genera of perennial Triticeae, which follows Barkworth and Dewey (1985). Little (1979) is our authority for trees and for classifying woody species as either trees or shrubs. Finally, scientific and common names of habitat types are as presented in the habitat type classification source documents cited in the introduction of this report.

RELATIONSHIP OF MAJOR TREE SPECIES TO FIRE

Wildfire plays a major role in forest succession throughout the Western United States, including forests in southeastern Idaho and western Wyoming. Table 3 summarizes the relative fire resistance of some of the principal conifers in southeastern Idaho and western Wyoming forests. Much of the information cited below has been previously reported in other fire ecology reports (Crane 1982; Fischer and Bradley 1987; Fischer and Clayton 1983).

Quaking Aspen (*Populus tremuloides*)

Quaking aspen's response to fire can be examined from two perspectives: (1) the individual stems (or suckers), which are not very resistant to fire, and (2) the clone itself, which is very fire resistant.

Individual stems have thin bark with a green photosynthetic layer. Stems are heat sensitive and easily killed by fire. If stems are not killed outright, a fire can cause basal scarring that provides the entry for fungal diseases. With or without fire, the stems are rather short-lived. Life span varies with area. In the Intermountain area, aspen maturity appears to take place in 80 to 100 years (Schier 1974). This compares with a life expectancy of 50 to 70 years in the Colorado Front Range (Mitton and Grant 1980). As individual stems in a stand mature, growth slows and stems become increasingly susceptible to disease and insect attack. The age when this process begins (60 to 120 years) (Mueggler 1989) may be related to site quality.

The aspen clone itself is very long-lived. It may survive for many centuries, periodically sending up new suckers to replace stems that die. Suckers originate from an extensive lateral root system. Most suckers are produced on roots within 3 to 4 inches (7 to 10 cm) of the soil surface (Fowells 1965). Following a severe fire where killing heat penetrates into the soil, some suckers may originate from roots down to 12 inches (30.5 cm) below the surface. Roots can extend downward to 3 ft (90 cm) (Buell and Buell 1959; DeByle 1991).

In the Western United States, sexual reproduction by aspen is very rare. Vegetative reproduction is stimulated by killing or removal of the overstory stems in the clone. When stems are killed or removed by fire, logging, or other disturbance, the source of auxin is removed. Auxin produced by apical buds, travels down the stem and represses sucker formation on the roots. Fire in an aspen clone has several effects. It releases sucker primordia on roots from auxin inhibition, removes canopy shade, and

Table 3—Relative fire resistance of some important conifers occurring in southeastern Idaho and western Wyoming (Flint 1925)

Species	Thickness of bark of old trees	Root habit	Resin in old bark	Branch habit	Stand habit	Relative inflammability of foliage	Lichen growth	Degree of fire resistance
Douglas-fir	Very thick	Deep	Moderate	Moderately low and dense	Moderate to dense	High	Heavy to medium	Very resistant
Lodgepole pine	Very thin	Deep[1]	Abundant	Moderately high and open	Open	Medium	Light	Medium
Engelmann spruce	Thin	Shallow	Moderate	Low and dense	Dense	Medium	Heavy	Low
Subalpine fir	Very thin	Shallow	Moderate	Very low and dense	Moderate to dense	High	Medium to heavy	Very low

[1]Lodgepole pine is generally deep rooted in well-drained, medium-textured soils. Root development is restricted by layers of coarse soils, impermeable layers, high water tables, or dense stand conditions (Pfister and Daubenmire 1975).

blackens the soil surface, which increases heat absorption. Increased soil temperatures aid in sucker production. Some suckers are produced by undisturbed clones; however, most suckers are generally suppressed and die in the shade of the canopy. Suckers will survive around the periphery of the stand and in gaps left by dying stems. Natural thinning is common in young aspen stands because of shade intolerance.

Moderate fires can rejuvenate deteriorating aspen. In the absence of fire, aspen may give way to conifers or break up and revert to shrub- or grass-dominated vegetation. Climax aspen responds to fire similarly, but it is less clear how important fire is in the life of the clone. Climax aspen clones in Utah may have dominated some sites for a thousand years or more (Mueggler 1976). Fire relationships in aspen-dominated communities are described in Fire Group Four.

Douglas-fir (*Pseudotsuga menziesii*)

Mature Douglas-fir is a relatively fire-resistant tree when compared with other western conifers. Saplings, however, are vulnerable to surface fires because of their thin, photosynthetically active bark, resin blisters, closely spaced flammable needles, and thin twigs and bud scales. A moderately low and dense branching habit of saplings enables surface fires to carry into the crown layer. Older trees develop a relatively unburnable, thick layer of insulative corky bark that provides protection against cool to moderately severe fires. Fire-resistant bark takes about 40 years to develop on moist (favorable) sites. Slow growth on poor sites may delay bark thickening. The protection offered by thickened bark is often offset by a tendency to have branches closely spaced along the length of the bole. The development of "gum cracks" in the lower trunk that streak the bark with resin provides a mechanism for serious fire injury. Lichens hanging from branches may provide a route for fire to reach crowns of mature trees.

Douglas-fir often occurs in open or scattered stands with sparse ground fuels, but it also grows in dense stands with continuous fuels underneath. Dense sapling thickets can form an almost continuous layer of flammable foliage about 10 to 26 ft (3 to 8 m) above ground that will support wind-driven crown fires. Even small thickets of saplings provide a route by which surface fires can reach the crowns of mature trees.

Heavy fuel accumulations at the base of the trees increase the probability of fire injury. Resin deposits often contribute to the enlargement of old fire scars during subsequent fires. The effects of fire on Douglas-fir communities are discussed in Fire Groups Two and Three.

Engelmann Spruce (*Picea engelmannii*)

Engelmann spruce is easily killed by fire. The dead, dry, flammable lower limbs, low-growing canopy, and thin bark contribute to the species' vulnerability. The shallow root system is readily injured by fire burning through the duff. Large old spruce may occasionally survive one or more light fires, but deep accumulations of resinous needle litter around their bases usually make them susceptible to fire damage. Survivors are often subjected to successful attack by wood-destroying fungi that enter through fire wounds. The high susceptibility of spruce to fire damage is offset in part by the relatively long fire-free interval that results from cool and moist site conditions.

Spruce is not an aggressive pioneer. It is a moderate seeder, but seed viability is rated good and the vitality persistent (Alexander and Sheppard 1984). Seedlings can survive on a wide variety of seedbeds. Initial establishment and early growth of seedlings may be slow, but is usually good when encouraged by shade and abundant moisture. Spruce seedlings can occur as members of a fire-initiated stand with lodgepole pine. Spruce is shade tolerant and will become established and grow beneath a lodgepole pine canopy. On sites where it is the indicated climax species, spruce eventually dominates the stand, but it takes a long period without any fire before this can occur.

Restocking takes place more quickly if some spruce trees survive within the burn than if regeneration is dependent on seed from trees at the edge of a burn. Pockets of spruce regeneration often become established around such surviving seed trees up to a distance of 300 ft (90 m), the effective seeding distance for spruce. Successful stand regeneration diminishes 100 to 150 years after establishment due to insufficient sunlight at ground level and to accumulating duff. At this point on most sites, the more tolerant subalpine fir begins to dominate in the understory. Fire Groups Six, Seven, and Eight describe role of fire in the subalpine environments where Engelmann spruce is a climax species.

Whitebark Pine (*Pinus albicaulis*)

Whitebark pine is a semitolerant or midtolerant species that has been observed as a pioneer inhabiting recently burned sites. It occurs as the potential climax species on alpine timberline and exceptionally dry sites but is a seral species in upper elevation subalpine fir and Engelmann spruce forests.

Whitebark pine is moderately fire resistant. It has a relatively thin bark and is susceptible to fire injury from hot surface fires that heat the tree's cambium. The characteristically open stand structure and its common occurrence on dry, unproductive sites tend to reduce whitebark pine's vunerability to fire. The fact that whitebark pine often reaches ages of 500 years or more reflects the reduced fire threat.

Whitebark pine may occur in small groups with lodgepole pine, subalpine fir, and Engelmann spruce. But most whitebark pine communities are comprised of open stands where the undergrowth is predominantly continuous low shrubs, forbs, and grasses. Occasionally larger shrubs and stunted trees are present.

Fires that burn in the undergrowth are usually of low to moderate severity. Severe fires are possible because the low, ground-hugging crowns of associated conifers can provide a fuel ladder. Downfall in the vicinity of mature trees locally increases crown fire potential.

Severe fires starting in lower elevations can spread throughout the upper-elevation forests to timberline. Although the open nature of a whitebark pine forest acts as a firebreak, many trees can be killed under these conditions. The most common fires are lightning fires that do not spread far. Nevertheless, during extended dry periods of high fire danger, fires may spread downhill into dense lower elevation forests.

Whitebark pine has a large, wingless seed that does not disperse by wind. Regeneration on burned sites is usually the result of seed germination from bird and rodent seed caches, especially those of Clark's nutcracker (*Nucifraga columbiana*). Whitebark pine may be a seral species in Fire Group Seven or dominate climax stands in Fire Group Eight.

Lodgepole Pine (*Pinus contorta*)

Individual mature lodgepole pine trees are moderately resistant to surface fires. Thin bark renders lodgepole pine vulnerable to death by cambium heating. Lodgepole pine is able to perpetuate itself on a site despite fire. Indeed, on most sites where lodgepole grows, fire is necessary for the species' continued dominance.

Lodgepole pine's key fire survival attribute is cone serotiny. Most lodgepole pine stands are composed of trees containing both serotinous and nonserotinous or open cones. The ratio of serotinous to nonserotinous cones seems to be related to the fire frequency for the site—the higher the fire frequency the greater the proportion of serotinous cones. During prolonged fire-free intervals, seed for regeneration will come mostly from open-coned trees. The stand will eventually become dominated by nonserotinous trees if fire does not occur.

A temperature of 113 °F (45 °C) is usually required to melt the resin that binds the scales of a serotinous cone. Heat from fire is far and away the most likely source of such extreme temperatures in the crowns of standing lodgepole pine. Following a stand-replacing fire, large quantities of highly viable seed are available to regenerate a site.

Aside from serotinous cones, other silvical characteristics that contribute to lodgepole pine's success in dominating a recently burned site are:

1. *Early seed production.* Cones bearing viable seed are produced by trees as young as 5 years old in open stands and by trees 15 to 20 years old in more dense stands. This feature not only allows relatively young stands to regenerate a site following fire, but also the seed from open cones on recently regenerated lodgepole can fill voids in the postfire seeding from serotinous cones.
2. *Prolific seed production.* Good cone crops occur at 1- to 3-year intervals with light crops intervening.
3. *High seed viability.* Viable seed has been found in 80-year-old serotinous cones.
4. *High survival and rapid growth.* High seedling survival and rapid early growth are characteristic of lodgepole, especially on mineral soil seedbeds exposed to full sunlight.

Lodgepole pine's success in revegetating a site following fire often results in dense, overstocked stands. Such stands are susceptible to stagnation, snow breakage, windthrow, dwarf mistletoe (*Arceuthobium americanum*) infestation, and mountain pine beetle (*Dendroctonus ponderosae*) attack. The combined effect of these factors is extreme buildup of dead woody fuel on the forest floor. Thus, the stage is set for another stand-destroying wildfire. Lodgepole pine occurs in Fire Groups Three through Eight.

Subalpine Fir (*Abies lasiocarpa*)

Subalpine fir is the least fire-resistant conifer in the Intermountain West because of its thin bark, resin blisters, low and dense branching habit, and moderate-to-high stand density in mature forests. As a result, fire most often acts as a stand-replacement agent when it burns through a subalpine fir forest. Even relatively cool ground fires can kill the cambium or spread into the ground-hugging branches and from there up into the crown.

Subalpine fir may begin producing cones when only 20 years old, but maximum seed production is by dominant trees 150 to 200 years old. Subalpine fir has the ability to germinate and survive on a fairly wide range of seedbeds.

Subalpine fir can occur in a fire-initiated stand with Douglas-fir, lodgepole pine, and other seral

species because it germinates successfully on a fire-prepared seedbed. But subalpine fir usually remains a slower growing, minor component dominated by less tolerant species.

Subalpine fir can exist better under low light conditions than most associated species. Engelmann spruce will, however, often grow faster than subalpine fir where light intensity exceeds 50 percent of full sunlight. Subalpine fir is shade tolerant and is the indicated climax species on many sites containing lodgepole pine. Where a seed source exists, the fir will invade and grow in the understory of lodgepole stands. Given a long enough fire-free period, subalpine fir will overtop lodgepole pine on Fire Group Six, Seven, and Eight sites, where it is usually the indicated climax.

Blue Spruce (*Picea pungens*)

Blue spruce is easily killed by fire. Its thin bark (0.75 to 1.5 inches [2 to 3.8 cm] thick at maturity) is evidently insufficient to protect the cambium, even from low fires (Preston 1940). In addition, blue spruce is slow to self-prune lower branches and the foliage is dense, allowing surface fires to crown. Despite its shallow root system, blue spruce is windfirm and may resist wind better than other spruces in fire-opened stands.

Blue spruce is a good to prolific seeder with full cone crops occurring every 2 or 3 years. Seed production begins at approximately 20 years and peaks between 50 and 150 years. Most seeds fall within 300 ft (91 m) of the upwind timber edge. Most natural germination takes place on mineral soil. Overhead light with side shade favors seedling development (Fechner 1985).

Blue spruce is the least shade-tolerant and most drought-tolerant spruce. It appears to be slightly more tolerant than Douglas-fir in Utah. It is less tolerant than subalpine fir. On some sites where it is considered the climax dominant, it may share dominance with Engelmannn spruce. It is commonly a member of riparian communities and frequently borders wet meadows.

Limber Pine (*Pinus flexilis*)

The degree of stem scorch usually determines the extent of fire injury to limber pines. Young trees are killed by any fire that scorches their stems. The bark of young limber pine is too thin to prevent cambium injury, even from a cool fire. Older trees are better able to withstand stem scorch from low-severity fires because the bark around the base of mature trees is often 2 inches (5 cm) thick. The needles of limber pine form into tight clusters around the terminal buds. This shields the buds from heat associated with crown scorch.

In many climax limber pine stands, fire plays a relatively minor role. Fuels are scarce and fires infrequent. Where limber pine is seral to other conifers, conditions are more productive and the effects of fire more important.

Keown (1977) conducted prescribed fire studies in central Montana limber pine stands. Study results indicated a strong relationship between fuel type, fire severity, and fire injury to limber pine. On sites where grass was the primary fuel and where trees were present as scattered individuals or open stands, fire severity was low and limber pine mortality was only about 20 percent. In similar situations with a dense shrub understory (primarily shrubby cinquefoil, *Potentilla fruticosa*) fire severity was high and limber pine mortality often reached 80 percent. Fires in grassland- or shrubland-forest transition zones were the most severe. Limber pines in these transition zones were often less than 10 ft (3 m) tall, with lower branches intermingled with ground fuels. Keown's study was conducted in a limber pine/bunchgrass vegetation type with much higher fine fuel loadings than can be expected on climax limber pine sites. The results may apply to more productive sites where limber pine is a seral species.

Limber pine is not dependent on fire to provide a favorable seedbed. Seed is distributed mainly by the Clark's nutcracker, which caches the large pine seeds for future consumption. Nutcrackers may cache seed on recent burns or on undisturbed areas.

Limber pine is a climax species in Fire Group One. It occurs as a seral species on drier microsites in all but the most mesic fire groups.

Rocky Mountain Juniper (*Juniperus scopulorum*)

Young juniper trees are easily killed by fire primarily because of their small size, thin bark, and compact crown. Fire has long been recognized as a means to control juniper because it does not resprout. Often young trees are killed just by scorching the crown and stem.

As juniper ages, the bark thickens and the crown develops a bushy, open habit. A hot fire can kill or severely damage such a tree, but the same tree may survive a cool fire. Low, spreading branches can provide a route for fire to enter the crown thereby increasing the potential for damage. Often large junipers will survive four to six fires.

The different effects of fire on young and old juniper trees are largely a function of the site. The species commonly occupies dry, subhumid environments that support limited undergrowth. When surface fuels are sparse, fire damage is minimal.

UNDERGROWTH RESPONSE TO FIRE

Many of the common shrubs and herbaceous plants that grow in forest and woodlands in the Rocky Mountains can renew themselves from surviving plant parts following fire. Other plants are quite susceptible to fire kill and often must reestablish or colonize from off-site seed sources in unburned areas within or immediately adjacent to the burned area.

Stickney (1982) described the process of postfire plant succession following fire in Northern Rocky Mountain forests:

> ...the severity of the disturbance treatment directly affects the representation of the survivor component in the postfire vegetation. Since survivors derive from plants already established at the time of disturbance, it is possible, by pretreatment inventory, to determine the potential composition for the survivor component. For this reason it also follows that forest stands with little undergrowth vegetation could be expected to have a sparse or limited survivor component following disturbance. In addition, if the survivor component is composed mostly of shade-tolerant climax-like species the rate of survivor recovery can be expected to be slow. Nearly all of our native forest shrub species are capable of surviving burning, and they can therefore be expected to function as survivors. A majority of the predisturbance forest herb species also demonstrated the ability to survive fire, particularly those species with underground stems (rhizome) or rootcrowns (caudex). As a generalization, the more severe the fire treatment to vegetation, the less the survivor component. In the drier, more open forest types this usually results in a reduction of amount, but not major changes in composition. However, in the moister forest types, where the undergrowth is made up of more mesic shade-tolerant species, marked changes in postfire composition can occur as increasing severity reduces survivor representation.
>
> The severity of disturbance treatment (particularly fire) influences the potential for colonizer presence in two ways: (1) the degree of severity creates the character of the ground surface on which colonizer seedlings germinate, and (2) it activates onsite stored seed. Generalizing, the more severe the disturbance treatment the more favorable the site becomes for colonizers. As the extent of exposed mineral soil increases, the ground surface becomes more favorable as a site for germination and establishment of colonizer plants. Increases in treatment severity also favor germination of ground-stored seeds by increasing their exposure to light or heat.
>
> Predicting the occurrence of colonizers in postdisturbance vegetation is much less certain than predicting for survivors, but knowledge of the previous succession history can provide the potential composition of residual colonizers. Locally this information is often available from an adjacent or nearby clearcut. Least predictable is the offsite colonizer component, for its occurrence is dependent on the timing of the disturbance to the availability and dispersal of offsite airborne seed. Even in this case reference to local clearcuts can provide some idea of the composition for the most common offsite colonizer species likely to occur.

Table 4 summarizes plant response to fire for some species that occur in southeastern Idaho and western Wyoming forests. The fire response information is generalized. Plant response to fire depends on many factors, including soil and duff moisture, plant vigor and phenological state, and the severity of the fire, especially in terms of the amount of heat that travels downward through the duff and upper layer of soil.

WILDLIFE RESPONSE TO FIRE

The effects of fire on wildlife are primarily secondary effects. Fire creates, destroys, enhances, or degrades favorable wildlife habitat (food supply, cover, shelter, physical environment), thereby causing changes in the subsequent occurrence and abundance of animal species on a burned area (fig. 1). Table 5 lists the probable effects of fire on some mammals, reptiles, and amphibians in eastern Idaho and western Wyoming forests. The indicated fire effects are inferred either from habitat requirements or from studies conducted on specific wildfire or prescribed fire areas. A major problem in attempting any generalization about the effects of fire on wildlife is the variation in fire intensity, duration, frequency, location, shape, extent, season, fuels, site, and soils (Lyon and others 1978).

Bird species' response to fire has been hypothesized by Kramp and others (1983) using a classification suggested by Walter (1977).

Four fire response categories are recognized in this classification: (1) fire-intolerant, (2) fire-impervious, (3) fire-adapted, and (4) fire-dependent. These classes are described as follows:

1. Fire-intolerant species decrease in abundance after fire and are present only in areas characterized by very low fire frequency and severity. Characteristic western species include the hermit thrush, red-breasted nuthatch, and brown creeper, which are closely associated with closed canopy forests. These birds prefer a dense nesting and foraging cover but do not use fire-opened habitat.

2. Fire-impervious bird species are unaffected by fire; they neither increase nor decrease because of fire. Bird species whose niche incorporates successional and climax community types may be expected to show the highest flexibility in response to fire.

Table 4—Summary of postfire survival strategy and fire response information of some plants occurring in forests of western Wyoming and southeastern Idaho (sources: Ahlenslager 1988; Armour and others 1984; Bradley 1986a,b,c,d, 1984; Britton and others 1983; Crane 1991, 1990a,b, 1989a,b,c; Crane and others 1983; Daubenmire and Daubenmire 1968; Fischer 1986; Fischer and Bradley 1987; Fischer and Clayton 1983; Freedman 1983; Fulbright 1987; Hickerson 1986a,b; Hironaka and others 1983; Keown 1978; Kramer 1984; Lotan and others 1981; Lyon 1971, 1966; Lyon and Stickney 1976; McLean 1969; McMurray 1987a,b,c,d,e, 1986a,b; Miller 1977; Morgan and Neuenschwander 1985; Mueggler 1965; Noste 1985; Noste and Tirmenstein 1990; Rowe 1983; Snyder 1991h; Stickney 1981; Tirmenstein 1991a,b,c, 1989, 1988a,b, 1987a,b,c; Uchytil 1989a,b,c; Viereck and Dyrness 1979; Viereck and Schandlemeier 1980; Volland and Dell 1981; Walkup 1991; Winkler 1987a,b,c; Woodard 1977; Wright 1972; Zager 1980; Zimmerman 1979.

Species	Fire survival strategy	Comments on fire response
SHRUBS AND SMALL TREES:		
Acer glabrum Rocky Mountain maple	Sprouts from surviving root crown or caudex.	Usually increases following fire but survival and response may be reduced by a severe fire.
Alnus sinuata Sitka alder	Sprouts from surviving root crown; on-site and off-site wind-dispersed seed.	Usually increases on site following fire. Early seed production (after 5 years) aids in this increase.
Amelanchier alnifolia Serviceberry	Sprouts vigorously from surviving root crown and rhizomes, often produces multiple stems.	Pioneer species; usually survives even severe fires especially if soil is moist at time of fire. Coverage may decrease and frequency increase following fire.
Arctostaphylos uva-ursi Kinnikinnick	May sprout from a root crown or caudex; regeneration from stolons more common. May have somewhat fire resistant seeds stored in soil.	Susceptible to fire-kill. Will survive some low severity fires when duff is moist and therefore not consumed by fire. May invade burned area from unburned patches.
Artemisia tridentata Big sagebrush	Wind dispersed seed. Subspecies *vaseyana* stores seed in the soil, which germinates as a result of fire-induced heating.	Very susceptible to fire-kill. Recovery is hastened when a good crop exists before burning.
Berberis (*Mahonia*) *repens* Creeping Oregon grape	Sprouts from surviving rhizomes which grow 0.5 to 2 inches (1.5 to 5 cm) below soil surface.	Moderately resistant to fire-kill. Usually survive all but severe fires that remove duff and cause extended heating of upper soil.
Ceanothus velutinus Snowbrush ceanothus	Soil-stored seed germinates following heat treatment; also sprouts from root crowns and roots following a cool fire.	Usually increases following fire, often dramatically.
Cercocarpus ledifolius Curlleaf mountain-mahogany	Weak sprouter; off-site wind-dispersed seed.	Seriously damaged by severe fires. Seeds need mineral soil to germinate.
Clematis columbiana Columbia virgins-bower	Sprouts from surviving root crowns.	Poorly documented.
Cornus canadensis Bunchberry	Sprouts from surviving rhizomes that grow 2 to 5 inches (5 to 13 cm) below soil surface.	Moderately resistant to fire-kill. Will survive all but severe fires that remove duff and cause extended heating of upper soil.

(con.)

Table 4 (Con.)

Species	Fire survival strategy	Comments on fire response
Cornus stolonifera (Sericea) Red-osier dogwood	Sprouts from surviving rhizomes or stolons (runners); fire-activated seed on-site in soil.	Susceptible to fire-kill but will survive all but severe fires that remove duff and cause extended heating of upper soil.
Holodiscus discolor Creambush ocean-spray	Regenerates from soil-stored seed or sprouts from surviving root crown.	Moderately resistant to fire-kill. Is often enhanced by fire.
Juniperus communis Common juniper	Long-viability on-site seed and bird dispersed off-site seed.	Very susceptible to fire-kill. Seed requires long germination period.
Juniperus horizontalis Creeping juniper	Fire activated on-site seed in soil; off-site animal-dispersed seed.	Fire response poorly documented.
Linnaea borealis Twinflower	Sprouts from surviving root crown located just below soil surface. Fibrous roots and (runners) at soil surface.	Susceptible to fire-kill. May survive some cool fires where duff is moist and not consumed. Can invade burned area from unburned patches.
Lonicera utahensis Utah honeysuckle	Sprouts from surviving root crown.	Often reduced coverage and frequency following fire.
Menziesia ferruginea Rusty menziesia	Sprouts from surviving root crown.	Susceptible to fire-kill. Moderate to severe fires reduce survival and slow redevelopment.
Pachistima myrsinites Mountain lover	Sprouts from surviving root crown and from buds along taproot.	Moderately resistant to fire-kill. Usually survives low to moderately severe fires that do not consume the duff and heat soil excessively. Usually increases.
Physocarpus malvaceus Mallow ninebark	Sprouts from surviving root crown or horizontal rhizomes.	Fire resistant. Resprouts well although spreading may be somewhat delayed.
Potentilla fruticosa Shrubby cinquefoil	Sprouts from surviving root crown.	Susceptible to fire-kill, but may survive low to moderate fires.
Prunus virginiana Common chokecherry	Sprouts from surviving root crown; occasionally from rhizomes; on-site seed.	Usually increases coverage following fire by prolific sprouting.
Purshia tridentata Antelope bitterbrush	A weak sprouter from root crown; rodent-dispersed seed and seed caches located on burned areas.	Very susceptible to fire-kill, especially in summer and fall. Decumbent growth form frequently sprouts, columnar form does so only weakly. Spring burns enhance sprouting, fall burns are best for regeneration by seed.
Ribes cereum Wax currant	A weak sprouter from root crown; fire-activated on-site seed in soil.	Susceptible to fire-kill. Seldom survives severe fire. Regeneration is favored by short duration low-severity fire.

(con.)

Table 4 (Con.)

Species	Fire survival strategy	Comments on fire response
Ribes lacustre Prickly currant	Sprouts from surviving root crown and rhizomes.	Resistant to fire-kill. Usually increases even after a severe fire. Seedlings may establish after low or moderate fires.
Ribes montigenum Alpine prickly currant	Sprouts from surviving root crown or caudex; germination of heat-stimulated on-site seed.	Fire response poorly documented.
Ribes viscosissimum Sticky currant	A weak sprouter, soil-stored seed may require heat treatment.	Susceptible to fire-kill. Relatively shade intolerant. May contribute substantially to postfire revegetation.
Rosa gymnocarpa Baldhip rose	Sprouts from surviving root crowns.	
Rosa woodsii Wood's rose	Sprouts from surviving root crowns.	Some ecotypes can spread by root sprouting.
Rubus parviflorus Thimbleberry	Sprouts from surviving rhizomes and root crown seedlings from soil-stored seed and possible bird-dispersed seed.	Enhanced by fire. Spreads vigorously from rhizomes; rapid recovery after fire.
Salix scouleriana Scouler willow	Multiple sprouts from root crown or caudex; off-site wind-borne seeds.	Resprouts vigorously after fire and seeds germinate readily on moist burned sites.
Sambucus racemosa Black (or red) elderberry	Sprouts from rhizomes and root crown; germination of fire-activated on-site seed in soil.	Seed germination may be extensive; response may decline with repeated burning.
Shepherdia canadensis Russet buffaloberry	Sprouts from surviving root crown and from buds along taproot.	Moderately resistant to fire-kill. Will usually survive cool to moderately severe fires that fail to consume duff.
Sorbus scopulina Mountain ash	Sprouts from deep-seated rhizomes.	Resprouts vigorously after fire.
Symphoricarpos albus Common snowberry	Sprouts vigorously from surviving rhizomes that are located between 2 and 5 inches (5 to 13 cm) below soil surface.	Resistant to fire-kill. Will usually survive even severe fires. Greatly enhanced by cool to moderately severe fires.
Symphoricarpos oreophilus Mountain snowberry	Sprouts from buds on root crowns and rhizomes; root crown sprouts originate from bud at 1 inch below the soil surface.	Has been described as a weak sprouter. May take several years to achieve preburn cover.
Vaccinium caespitosum Dwarf huckleberry	Sprouts from shallow rhizomes; off-site animal-transported seed.	Sprouts may quickly reoccupy a site after low to moderate severity fires.
Vaccinium globulare Globe huckleberry	Sprouts from dense network of shallow and deep rhizomes.	Moderately resistant to fire-kill. Will usually survive cool to moderately severe fires. May attain preburn cover within 3 to 5 years.

(con.)

Table 4 (Con.)

Species	Fire survival strategy	Comments on fire response
Vaccinium scoparium Whortleberry	Sprouts from surviving rhizomes that grow in duff layer or at surface of soil.	Moderately resistant to fire-kill. Will usually survive cool to moderately severe fires that fail to consume the lower layer of duff.
GRAMINOIDS:		
Agropyron cristatum Crested (or Fairway) wheatgrass	Low flammability growth habit; deep underground stems.	Varies with season and fire severity; growth may be favored by late summer fire. Spring fire can cause decreased yields for several years.
Calamagrostis canadensis Bluejoint reedgrass	Invader, wind-disseminated seed; also an enduring sprouter.	Increases on wet to moist postfire sites.
Calamagrostis rubescens Pinegrass	Sprouts from surviving rhizomes that grow within the top 2 inches (5 cm) of soil.	Moderately resistant to fire-kill. Will usually survive cool to moderately severe fires that do not completely consume duff. Burned areas are often successfully invaded by pinegrass.
Carex geyeri Elk sedge	Sprouts from surviving rhizomes.	Invades burned areas and forms dense stands. Often increases following fire.
Carex rossii Ross sedge	Seed stored in duff or soil germinate when heated. Sprouts from surviving rhizomes.	Increased coverage usually results following most fires severe enough to heat but not completely consume duff. Often increases.
Elymus glaucus Blue wildrye	On-site surviving root crown or caudex; on-site seed may survive some fires.	Seedlings establish and develop rapidly on burned sites.
Festuca idahoensis Idaho fescue	Seed germination and survival of residual plant.	Susceptible to fire-kill. Response will vary with severity of fire and physiological state of plant. Can be seriously harmed by hot summer and fall fires. Only slightly damaged during spring or fall when soil moisture is high.
Festuca thurberi Thurber fescue	On-site surviving root crown; off-site wind-dispersed seed.	Response may be poor where accumulated litter results in severe soil heating.
Koeleria cristata Prairie junegrass	Seed germination and residual plant survival.	Susceptible to fire-kill. Response will vary according to fire severity and physiological state of plant.
Leucopoa (*Hesperochloa*) *kingii* Spike fescue	On-site surviving rhizomes; off-site wind-dispersed seed.	Often increases following fire.

(con.)

Table 4 (Con.)

Species	Fire survival strategy	Comments on fire response
Leymus cinereus Giant wildrye	Growth habit avoids soil heating; sprouts from surviving root crown and rhizomes.	Recovers rapidly, especially after dormant season fires.
Luzula hitchcockii Smooth woodrush	Sprouts from surviving rhizomes.	Often a slight increase following fire.
Pseudoroegneria spicata Bluebunch wheatgrass	Seed germination and some sprouts from surviving growing points.	Usually not seriously damaged by fire. Response depends on severity of fire and physiological state of plant. Damage will be greatest following dry year.
FORBS:		
Achillea millefolium Common yarrow	Sprouts from extensive rhizomes.	Survives most fires, can increase cover rapidly.
Actaea rubra Baneberry	Sprouts from thick underground caudex; off-site animal-transported seed.	Vigorous growing sprouts may occur the first year after fire.
Arnica cordifolia Heart-leaf arnica	Sprouts from surviving rhizomes that creep laterally from 0.4 to 0.8 inches (1 to 2 cm) below soil surface. Wind-dispersed seed.	Susceptible to fire-kill. Shoots produce small crowns within the duff, easily killed by all but cool fires when duff is moist. May rapidly invade burned area via wind-borne seed.
Arnica latifolia Broadleaf or mountain arnica	Sprouts from laterally creeping rhizomes.	Susceptible to fire-kill. Will usually survive cool to moderately severe fires. May exhibit rapid initial regrowth accompanied by heavy flowering and seedling establishment.
Astragalus miser Weedy milkvetch	Sprouts from buds along surviving taproot 2 to 8 inches (5 to 20 cm) below root crown.	Resistant to fire-kill. Can regenerate from taproot even when entire plant crown is destroyed. Can send up shoots and set seed the first year. May increase dramatically following fire. Poisonous to sheep and cattle.
Balsamorhiza sagittata Arrowleaf balsamroot	Regrowth from surviving thick caudex.	Resistant to fire-kill. Will survive even the most severe fire. Increases in frequency and density after fire.
Disporum trachycarpum Wartberry fairy-bell	Sprouts from rhizomes.	*Disporum hookeri* is initially decreased by fire but recovers to preburn levels relatively rapidly.
Dracocephalum parviflorum American dragonhead	Germination of residual seed in duff.	Dramatic increase following fire. Decreases after second year.

(con.)

Table 4 (Con.)

Species	Fire survival strategy	Comments on fire response
Epilobium angustifolium Fireweed	Wind-blown seed and sprouts from rhizomes.	Needs mineral soil to establish, can persist vegetatively and flower the first summer following a fire. Large increase following fire.
Equisetum arvense Field horsetail	Spreading rhizomes and wind-dispersed propagules.	Frequency unchanged or increased after fire. Especially favored by moist mineral soil exposure.
Fragaria virginiana Wild strawberry	Sprouts from surviving stolons (runners) at or just below soil surface.	Susceptible to fire-kill. Will often survive cool fires that do not consume duff because of high duff moisture content.
Galium triflorum Sweetscented bedstraw	Sprouts from surviving rhizomes.	Susceptible to fire-kill. Usually a sharp decrease following severe fire. Can increase following spring and fall fires.
Osmorhiza chilensis Mountain sweet-root	Short shallow roots; barbed, animal-dispersed seeds.	Moderately fire-resistant; temporary increase after fire.
Pyrola secunda Sidebells pyrola	Sprouts from rhizomes surviving mostly in the duff or at soil surface.	Susceptible to fire-kill. Coverage frequently reduced following fire. May survive cool fires when duff moisture is high.
Senecio streptanthifolius Cleft-leaf groundsel	Nonrhizomatous, regenerates from off-site seed.	
Smilacina racemosa False spikenard	Sprouts from surviving stout creeping rhizomes.	Moderately resistant to fire-kill. May be killed by severe fires that remove duff and heat soil excessively. Usually maintains prefire frequency.
Smilacina stellata Starry Solomon-plume	Sprouts from surviving creeping rhizomes.	Moderately resistant to fire-kill. May be killed by fires that remove duff and heat upper soil. Frequency often reduced following fire.
Streptopus amplexifolius Claspleaf twistedstalk	Extensively rhizomatous.	Decreased by fire.
Thalictrum occidentale Western meadowrue	Sprouts from surviving rhizomes.	Susceptible to fire-kill. Frequency usually reduced following fire. May survive cool fires that do not consume duff.
Xerophyllum tenax Beargrass	Sprouts from a surviving stout, shallow rhizome.	Susceptible to fire-kill. Will survive cool fires that do not consume lower duff. Resprouts will flower vigorously until new overstory canopy developed.

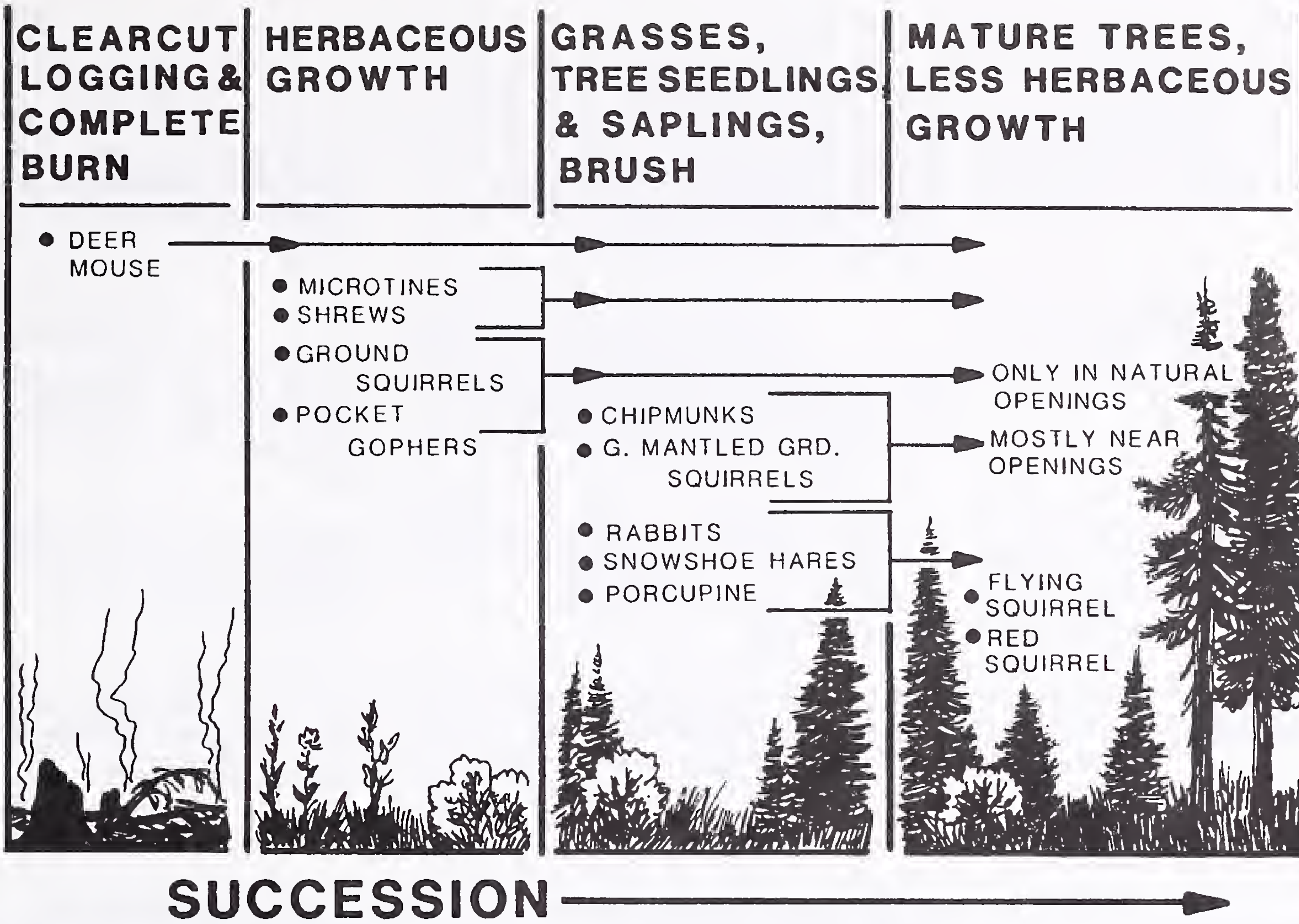

Figure 1—Small mammals found in the successional stages after clearcut logging and burning (Ream and Gruell 1980).

Table 5—Probable effects of fire on some mammals, reptiles, and amphibians occurring in southeastern Idaho or western Wyoming (sources: Bernard and Brown 1977; Crane and Fischer 1986; Fischer and Bradley 1987; Snyder 1991a,b,c,d,e,f,g,h,i,j; Thomas 1979; Verner and Bass 1980)

Species	Habitat considerations	Fire effects
INSECTIVORA (insect eaters):		
Masked shrew *Sorex cinereus*	Prefers moist situations in forest or open. Requires a mat of ground vegetation for cover; stumps, logs, and slash piles for nest sites.	May be temporarily eliminated from severe burns where duff and ground cover are absent. Some direct mortality of nestlings possible.
Dwarf shrew *Sorex nanus*	Prefers the Douglas-fir zone. Also frequents alpine and subalpine rock-slide areas.	Should be relatively impervious to fire in rocky habitat. May suffer temporary reduction where dependent on forest habitat.
Vagrant shrew *Sorex vagrans*	Prefers streamsides, marshes and bogs, but also takes cover in moist soil, matted ground vegetation, or debris. Feeds and nests in stumps and rotten logs.	May be temporarily eliminated from severe burns where duff, ground cover, and debris are absent. Some direct mortality of nestlings possible.
Dusky shrew *Sorex obscurus*	Habitats include coniferous forest, marsh, and dry hillsides. Nests in stumps, bogs, and debris.	Adversely impacted by fires that consume surface debris.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Water shrew *Sorex palustris*	Prefers riparian areas at middle and high elevations. Requires small, cold streams and wet areas with protected banks and ground cover.	May be eliminated from severely burned areas where duff and streamside cover have been removed.
CHIROPTERA (bats):		
Little brown myotis *Myotis lucifugus*	Common in forest and at the forest edge. Requires snags and tree holes for roosting and for maternity colony sites.	Severe fires may destroy roosting and breeding sites. Relatively impervious to cool and moderate fires.
Long-eared myotis *Myotis evotis*	Occurs in coniferous woodland as well as in spruce-fir zone. Uses snags and tree holes for roosting and for breeding colonies.	Severe fires may destroy roosting and breeding sites; otherwise relatively impervious to fire.
Small-footed myotis *Myotis subulatus*	Most common in ponderosa pine zone. May use hollow trees and snags for roosting and breeding.	Severe fires may destroy roosting and breeding sites but have little impact on populations.
LAGOMORPHA (pikas, hares, and rabbits):		
Pika *Ochotona princeps*	Prefers high-altitude talus slopes adjacent to forest openings containing grasses and forbs.	Relatively impervious to fire. Severe fire may create favorable forest openings with abundant grass-forb food supply.
Snowshoe hare *Lepus americanus*	Prefers dense shrubs in forest openings or under pole-sized trees for food and cover. Uses downed logs for cover and nest sites.	Temporarily eliminated from severe burns. Populations may increase dramatically as shrubs resprout and dominate the area. Will continue to use many less than severe burns.
White-tailed jackrabbit *Lepus townsendi*	Prefers early grass-forb successional stages.	May increase where fire removes overstory and creates meadow-type habitat.
RODENTIA (gnawing mammals):		
Least chipmunk *Eutamias minimus*	Present in high mountain coniferous forests. Requires open areas with stumps, downed logs, and shrubs or other high vegetation for cover.	Temporarily decreases following severe fire that reduces cover. Return first season after fire and usually abundant by third postfire year.
Yellow-pine chipmunk *Eutamias amoenus*	Prefers shrub, seedling, and sapling stages of forest succession. Usually abundant in open ponderosa pine forests and edges. Needs shelter of downed logs, debris, or shrubs. Often burrows under downed logs and stumps.	Recent burns with stumps and shrubs are favored habitat, especially as seed- and fruit-producing annuals become available.
Cliff chipmunk *Eutamias dorsalis*	Range includes P-J and conifer woodlands. Occupies sparsely vegetated rocky slopes.	Relatively impervious to fire.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Uinta chipmunk *Eutamias umbrinus*	Frequents ponderosa pine forest and up through the subalpine. Nests in burrows, hollow logs, and in rock crevices.	Hot surface fire may consume desirable ground debris.
Yellow-bellied marmot *Marmota flaviventris*	Prefers rocky outcrops or talus slopes; forest openings up through spruce-fir zone. Uses downed logs for cover; burrows under tree roots. Feeds on green grass and forbs.	Relatively impervious to fire. Benefits from fire-created openings dominated by grass and forbs.
Uinta ground squirrel *Citellus armatus*	Prefers moist habitats with lush vegetation and soft soil; subalpine meadows; forest edges.	May increase dramatically on areas where fire has killed overstory; may be favored by increased light and temperature as well as increase in herbaceous growth.
Belding ground squirrel *Citellus beldingi*	Generally restricted to mountain meadows and early successional stages in ponderosa pine, lodgepole pine, and Douglas-fir forests. Nests underground; requires friable soil. Feeds on grasses, forbs, seeds, bulbs, etc.	Benefits from fire-created openings that produce abundant herbaceous undergrowth.
Golden-mantled ground squirrel *Citellus lateralis*	Widespread from ponderosa pine forest to alpine meadows. Most abundant in open forests lacking a dense undergrowth or understory. Needs downed logs, stumps, or rocks for cover. Burrows for shelter.	Generally increases on recently burned areas due to increased abundance of forbs, providing adequate escape cover exists.
Red (pine) squirrel *Tamiasciurus hudsonicus*	Found in late successional forests. Nests in tree cavities and branches. Feeds on conifer seeds, nuts, bird eggs, fungi. Uses downed logs for cover.	Essentially eliminated following stand-replacing fires. Cavities in fire-killed trees may be used for dens but only if surrounded by live trees.
Northern flying squirrel *Glaucomys sabrinus*	Prefers a mature forest. Requires snags and trees with nest cavities. Also requires an abundance of downed logs. Feeds on conifer seed, serviceberries, and mushrooms.	Same as for red squirrel except may forage for fungi in recent burns.
Northern pocket gopher *Thomomys talpoides*	Prefers disturbed areas of secondary vegetative growth; also pine forests, alpine parks, and meadows. Occurs mostly in deep sandy soils but also in clay and gravelly soils. Requires an herbaceous food source, especially annual forbs.	Population densities usually increase on areas burned by fires that open canopy and disturb the soil, resulting in undergrowth of early successional forbs and grasses.
Beaver *Castor canadensis*	Requires streams or lakes bordered by stands of aspen, alder, birch, poplars, or willow for food and building materials.	Usually increases following fires that initiate a successional sequence that includes aspen as an intermediate stage.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Deer mouse *Peromyscus maniculatus*	Ubiquitous. Occurs in most successional stages of most habitat types. Nests in burrows, trees, and stumps. Uses downed logs for nesting sites and cover.	Populations reduce immediately following fire but significantly increase as soon as rain settles the ash. Most abundant small mammal on severely burned areas.
Bushy-tailed woodrat *Neotoma cinerea*	Prefers rocky situations. Dens in rock crevices; sometimes in hollow logs. Gathers conifer seed, berries, fungi, twigs, shoots, and green vegetation.	Relatively impervious to fires that occur in high-elevation rocky habitat. Usually not abundant on recent burns.
Southern red-backed vole *Clethrionomys gapperi*	Prefers mesic areas within coniferous forests that contain abundance of large debris on forest floor and undergrowth of shrubs and herbs. Feeds on conifer seed, bark, fungi, and green vegetation. A coniferous overhead tree canopy is preferred.	Usually eliminated from severely burned areas within 1 year after fire. If overstory trees are present and survive, favorable habitat may return 7 or more years after the fire.
Heather vole *Phenacomys intermedius*	Prefers open grassy areas and forest openings, but also riparian zones. Nests under rocks, stumps, or other debris on forest floor. Often found in association with huckleberry.	Benefits from forest openings and early successional undergrowth that result from moderate to severe fires. Severe surface fires may destroy nesting habitat.
Meadow vole *Microtus pennsylvanicus*	Requires a mat of ground cover for runways, palatable herbs, conifer seed, and moisture. Uses downed logs for cover and nest sites. Usually found near streamside.	Usually eliminated from severe burns where surface organic layer is absent. The wet nature of preferred habitat tends to resist fire.
Montane vole *Microtus montanus*	Habitat includes wet areas and mountain meadows within a relatively broad elevational range. Forages on ground for succulent stems and leaves of grasses and forbs. Constructs underground burrows.	Benefits from fire-created openings that support an undergrowth of grasses, sedges, and other wet site forbs.
Long-tailed vole *Microtus longicaudus*	Widespread in wet mountain meadows and forest edge, often near streams. Requires a grass-sedge-forb food source. Less restricted to runways and dense grass than other *Microtus*.	Use increases with removal of tree canopy especially on moist north slopes.
Water vole *Arvicola richardsoni*	Restricted to alpine marshes, willow-lined streambanks, and grass and sedge areas of the alpine and subalpine forests. Nests under roots, stumps, and logs.	Relatively impervious to fire. Severe fire that removes streamside cover may result in temporary loss of habitat.
Muskrat *Ondatra zibethica*	Occupies cattail marshes, banks of ponds, lakes, or slow-moving streams. Requires a source of succulent grasses or sedges, or other aquatic vegetation.	Periodic fire retains marshes in a subclimax state and removes unfavorable vegetation that crowds out useful plants.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Western jumping mouse *Zapus princeps*	Requires a well-developed extensive herbaceous layer along edge of rivers, streams, lakes, or other wet areas and moist soil. Uses downed logs for cover and nest sites. Eats seed, grass, and forbs.	Generally eliminated from severe burns that lack the required vegetative cover.
Porcupine *Erethizon dorsatum*	Prefers medium and old-age conifer stands of less than 70 percent crown closure and containing shrubs and herbs. Uses hollow logs and tree cavities for dens.	Use of severely burned areas curtailed especially if overstory is killed. May continue to use light and moderate burns.
CARNIVORA (flesh-eaters):		
Coyote *Canis latrans*	Widespread occurrence in most habitats and most successional stages. Uses hollow logs or stumps for dens. Preys on mice.	Increased use of burned areas that support abundant small mammal populations.
Gray wolf *Canis lupus*	Highly adaptable but probably restricted to wilderness forests. Preys on other mammals.	Probable increased use of burned areas that support an abundant population of prey species.
Red fox *Vulpes vulpes*	Prefers open areas in or near forest. Uses hollow stumps and logs for dens. Food includes berries, insects, birds, rodents, squirrels, rabbits, and other small mammals.	Benefits from fires that create favorable habitat for small mammal prey species, especially those that enhance snowshoe hare populations.
Grizzly bear *Ursus arctos*	Prefer open, shrub communities, alpine and low-elevation meadows, riparian areas, seeps, alpine slabrock, and avalanche chutes.	Fire can promote and maintain important berry-producing shrubs and forbs. Fire can adversely affect whitebark pine nut supplies.
Black bear *Ursus americanus*	Prefers mature forests mixed with shrubfields and meadows. Omnivorous. Requires windfalls, excavated holes, or uprooted or hollow trees for den sites.	Benefits from abundant regeneration of berry-producing shrubs following fire. Severe fires may destroy favorable den sites.
Raccoon *Procyon lotor*	Very adaptable to environmental change; in riparian situations; along marshes, streams, and lakes. Uses hollow trees and downed logs for dens. Omnivorous.	Relatively impervious to fire because of mobility and wide ecological amplitude.
Marten *Martes americana*	A forest dweller; requires relatively dense climax or near-climax situation. Uses tree or snag cavities and hollow stumps for nest sites. Food includes tree squirrels, chipmunks, mice, berries, and insects.	Eliminated from severely burned stands. Benefits from vegetative mosaics resulting from periodic small fires because of increased food supply. Burns containing adequate cover may be used for feeding during summer and fall.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Fisher *Martes pennanti*	Prefers forest of large trees with many windfalls and downed logs. Nests in tree holes, hollow logs, and snags. Eats squirrels, porcupines, woodrats, mice, rabbits, insects, and berries.	Preferred habitat is adversely affected by severe fire. Benefits from increase in prey species on burns adjacent to favorable habitat. Adapts better to early successional stages than marten.
Ermine (short-tail weasel) *Mustela erminea*	Prefers mature dense forest for breeding and resting; meadows or other forest openings for hunting. Dens often located in hollow logs and snags. Voles are an important prey; also mice, shrews, and chipmunks.	Adversely affected by severe fire that removes ground debris or kills overstory trees. Benefits from increased biomass of prey species that usually results on fire-created grass-forb successional stages.
Long-tailed weasel *Mustela frenata*	Ubiquitous—common in most habitats. Prefers open areas and young pole stands. Den sites include logs, stumps, and snags. A major predator of voles and mice. Also feeds on gophers, birds, insects, and vegetation.	Benefits from increased biomass of prey species usually found on recently burned areas.
Mink *Mustela vison*	May occur in any habitat containing fish-supporting marshes, lakes, and streams. Hollow logs and tree stumps along streams may be used for den sites.	Relatively impervious to most fires. May be adversely affected where fire removes streamside cover and debris.
Badger *Taxidea taxus*	Grass-forb stages of conifer forest succession is a preferred habitat. Likes **deep**, friable soil for burrowing and rodent capturing.	Benefits from fires that result in grass-forb successional stages because of the abundant rodent populations that are often present.
Western spotted skunk *Spilogale gracilis*	Habitat includes rocky and brushy areas in woodlands and chaparral. Prefers seedling-sapling stage. Den sites include rock outcrops, ground burrows, hollow logs, stumps, snags, or brush piles. Eats mostly insects and small rodents, also reptiles, amphibians, birds, eggs, and plant matter.	Moderate to severe fires may temporarily impact den sites and food supply.
Striped skunk *Mephitis mephitis*	Prefers early successional stages of forest but may be found in all stages and cover types. Uses hollow logs, stumps, and snags for den sites. Food includes large insects and small rodents.	Relatively impervious to fire. Benefits from increased biomass of prey species that usually occur on severe burns.
River otter *Lutra canadensis*	Occurs along streams, marshes, and lakes. Dens in bank. Aquatic.	Essentially impervious to fire. Severe fires may destroy essential escape cover along streams, thereby adversely affecting use.
Mountain lion (cougar, puma) *Felis concolor*	Found throughout all habitat types and successional stages. Highly mobile. Hunts deer, hares, rodents, and porcupines.	Often flourishes on recently burned areas due to increased prey availability.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Lynx *Felis lynx*	Primarily in dense coniferous forests at higher elevations. May den in hollow logs. Snowshoe hare is an important prey species.	Benefits from fire-initiated shrub stages of succession that support large populations of snowshoe hare.
Bobcat *Felis rufus*	Found in most habitats and successional stages; shrub-sapling stages being especially desirable. May establish den under large logs or in hollow logs. Preys on rodents, reptiles, and invertebrates.	Relatively impervious to fire. Benefits from any fire-induced increase in availability of prey species.
ARTIODACTYLA (even-hoofed mammals):		
Elk *Cervus elaphus*	Prefers semiopen forest but with areas of dense cover for shelter. Requires food supply of grass, forbs, and shrubs, especially Scouler willow, maple, serviceberry, redstem, and chokecherry.	Severe burns usually experience a decline in first-year use; then an increase as preferred browse species become available. Moderate fires in forest may remove ground debris and other obstructions to movement.
Mule deer *Odocoileus hemionus*	Occupies a wide range of habitats, including open montane and subalpine coniferous forest; forest edges, woodlands, and shrubfields. Shrub-seedling-sapling stage of succession preferred. Needs trees and shrubs for winter range. Preferred food includes tender new growth of palatable shrubs—ceanothus, cherry, mountain-mahogany, bitterbrush; many forbs and some grasses.	Fire may improve winter nutrition in grassland and mountain shrub communities by increasing the amount of green grasses. Often use declines during the first postburn year and then increases in subsequent years. Where antelope bitterbrush is an important winter range species, moderate to severe fires may be detrimental.
Whitetail deer *Odocoileus virginianus*	Prefers dense forest; rough, open shrublands; thickets along streams and woodlands. Diet includes shrubs, twigs, fungi, grasses, and forbs.	Fire-initiated early successional stages, supporting new growth of grasses, forbs, and shrubs provide a preferred food source.
Moose *Alces alces*	Prefers subclimax forests with lakes and swamps. Ideal habitat includes a mosaic of numerous age classes and distribution of aspen and associated trees and shrubs within the wintering range.	Fires that result in abundant aspen and willow regeneration create a preferred habitat. Optimal successional stage occurs from 11 to 30 years following a severe fire.
Bighorn sheep (mountain sheep) *Ovis canadensis*	Preferred habitat characterized by rugged rocky mountain slopes with sparse trees and adjacent to alpine meadows. Feeds on alpine shrubs and forbs in summer; shrubs and perennial grasses in winter.	Canopy removal by fire may yield increased productivity of undergrowth and makes available more open habitat thereby dispersing populations and reducing incidence of lungworm infections. Fire may retard successional advance of alpine grasslands and improve productivity and palatability of important forage species. Fire can improve nutrition in mountain shrublands by increasing availability of green grass.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
CAUDATA (salamanders):		
Tiger salamander *Abystoma tigrinum*	Found in and near pools, ponds, lakes, and streams. Adults sometimes burrow in decayed logs in damp forest situations.	Impervious to fire except for minor direct mortality in severe fire situations.
SALIENTIA (frogs and toads):		
Bullfrog *Rana catesbeiana*	Inhabits lakes, marshes, pools, ponds, reservoirs, and streams. Hides under debris at water's edge.	Relatively impervious to fire.
Spotted frog *Rana pretiosa*	Highly aquatic.	Impervious to fire.
Leopard frog *Rana pipiens*	Found near water. In summer it inhabits swamps, grassy woodland, or short grass meadows.	Generally impervious to fire. Some direct mortality possible from fast-spreading surface fire.
Canyon tree frog *Hyla arenicolor*	Found near streams in ponderosa pine and riparian forest zones.	Relatively impervious to most fires although severe fire can destroy favorable forest floor habitat.
Chorus frog *Pseudacris triseriata*	Occupies high grasslands and mountain forests. Inhabits marshes, meadows, lake margins, and grassy pools. Usually found on the ground or in low plants.	Relatively impervious to fire because of wet habitat.
Boreal toad (western toad) *Bufo boreas*	Found in or near water. Burrows in loose soil. Breeds in open water. Feeds on insects.	Relatively impervious to fire.
Rocky Mountain toad (Woodhouse's toad) *Bufo woodhousei*	Diverse habitat, found wherever sufficient moisture is found, prefers sandy areas, breeds in open water.	May suffer temporary loss of cover, breedings sites unaffected.
CHELONIA (turtles):		
Painted turtle *Chrysemys picta*	Highly aquatic. Basks near the water on mudbanks, rocks, and logs.	Impervious to fire.
SQUAMATA (snakes and lizards):		
Sagebrush lizard *Sceloporus graciosus*	Favors sagebrush but also occurs in P-J woodland and ponderosa pine forest. Likes scattered low shrubs on fine, gravelly soil. Eats insects, spiders, ticks, snails, and other small animals.	Fires that consume forest floor vegetation and debris can destroy favorable habitat conditions.
Rubber boa (Rocky Mountain boa) *Charina bottae*	Found near streams and meadows in all forest types; prefers pole to mature stands. Hides in rotting logs and bark of fallen and standing dead trees. Feeds on rodents, insects, and lizards on forest floor.	Severe surface fire can remove cover and temporarily reduce abundance of prey species.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Gopher snake (bullsnake) *Pituophis melanoleucus*	Highly adaptable species; occupies a variety of habitats. Mainly hunts on surface for small mammals.	Relatively impervious to fire because of wide ecological amplitude.
Common garter snake (red-sided garter snake; valley garter snake) *Thamnophis sirtalis*	Widely distributed in many different habitats that include a water source. Diet largely aquatic but includes small mammals.	Impervious to fire.
Western terrestrial garter snake *Thamnophis elegans*	Found in all successional stages of all habitat types near permanent or intermittent streams and ponds.	Relatively impervious to fire because of its tendency to be close to water.
Western rattlesnake *Crotalus viridis*	Highly variable habitats, including open woodlands to mountain forests. Often found in rock outcrops. Hunts on surface for rodents, ground squirrels, and mice.	Relatively impervious to fire except for possible direct mortality in severe surface fire situations. Such fires may also cause a temporary reduction in prey species.
Smooth green snake *Opheodrys vernalis*	Inhabits damp grassy areas, meadows, fields, boggy areas, streamsides, and rock areas interspersed with grass.	Relatively impervious to fire unless severe drying of its habitat permits burning. Hunting may be inhibited until vegetation greens up and provides camouflage.

3. Fire-adapted species are associated with habitat that is characterized by recurring fires of various severity. These species, however, are not dependent on fire-influenced habitat. Fire-adapted species may also occupy areas with the same frequency-severity ratio as fire-intolerant species. Fire-adapted birds include those that use both dense canopy areas and openings; a predator such as the sharp-shinned hawk is an example. Such birds benefit by increased hunting success in recent burns but generally nest in unburned habitat.

4. Fire-dependent species are associated with fire-dependent and fire-adapted plant communities. When fire frequency decreases, these plant communities shift to fire-neutral or fire-intolerant types, and fire-dependent species are unable to persist. The blue grouse may be an example. The bird depends on medium to large fire-created forest openings with shrub-grass-forb vegetation for breeding, adjacent to dense foliage conifers for roosting and hooting.

Table 6 presents the hypothesized fire tolerance of some bird species occurring in eastern Idaho and western Wyoming.

FIRE USE CONSIDERATIONS

Fire management applications of fire ecology information are presented at the end of each Fire Group discussion. The possible use of fire to accomplish certain resource management objectives is suggested in these fire management presentations. The following fire use considerations apply generally to all Fire Groups.

Fuels

Estimates of surface fuel loadings are required to accurately predict fire behavior. This information serves as input to mathematical models of fire spread and intensity such as FIREMOD (Albini 1976) and BEHAVE (Burgan 1987; Burgan and Rothermel 1984). Uses of fuel loading information include fire danger rating and fire behavior prediction for fire dispatching, presuppression planning, and fuel management (Brown and Bevins 1986).

Published fuel data for eastern Idaho and western Wyoming are scant. Brown and Bevins (1986) described loadings for fire groups similar to those presented herein. Figure 2 shows the range of loading

Table 6—Hypothesized fire tolerance of some bird species occurring in southeastern Idaho or western Wyoming (adapted from Kramp and others 1983)[1]

Fire intolerant	Fire impervious	Fire adapted	Fire dependent
Ash-throated flycatcher	American crow	American kestrel	Blue grouse
Black-capped chickadee[2]	American robin	American robin	House wren
Black-throated gray warbler	Black-billed magpie	Black-headed grosbeak	Mourning dove
Blue-gray gnatcatcher	Blue-winged teal	Blue grosbeak	Sandhill crane
Brewer's sparrow	Brown-headed cowbird	Blue-winged teal	Wild turkey
Brown creeper	Canada goose	Brewer's sparrow	
Burrowing owl	Cedar waxwing	Canada goose	
Cassin's finch[2]	Clark's nutcracker	Cassin's kingbird	
Chipping sparrow	Cliff swallow	Clark's nutcracker	
Golden-crowned kinglet	Common raven	Cliff swallow	
Grasshopper sparrow	Common snipe	Common nighthawk	
Great horned owl	Eastern kingbird	Cooper's hawk	
Hammond's flycatcher	European starling	Dark-eyed junco	
Hermit thrush	Gadwall	Downy woodpecker	
Mountain chickadee[2]	Great blue heron	Fox sparrow	
Goshawk	Green-tailed towhee	Hairy woodpecker	
Horned lark	Lark bunting	House wren	
Northern harrier	Loggerhead shrike	Killdeer	
Pine siskin	McGillivray's warbler	Lark sparrow	
Pygmy nuthatch	Mallard	Lazuli bunting	
Red-breasted nuthatch[2]	Mourning dove	Mallard	
Red crossbill	Northern flicker	Mountain bluebird	
Ruby-crowned kinglet	Northern pintail	Northern flicker	
Rufous-sided towhee[2]	Red-winged blackbird	Northern harrier	
Sharp-shinned hawk	Snowy egret	Northern pintail	
Solitary vireo	Song sparrow	Poor-will	
Western flycatcher	Stellar's jay	Rufous-sided towhee	
Western tanager[2]	Townsend's solitaire	Savannah sparrow	
White-crowned sparrow[2]	Turkey vulture	Snowy egret	
Yellow-rumped warbler[2]		Three-toed woodpecker	
Yellow warbler		Tree swallow	
		Vesper sparrow	
		Violet-green swallow	
		Western bluebird	
		Western kingbird	
		Western meadowlark	
		Western screech owl	
		Western wood pewee	
		Wild turkey	
		Williamson's sapsucker	
		Yellow-bellied sapsucker	

[1]Assignment of a species to one or more categories is based, in most cases, on limited data and opinion. Definitions in the text for each category should be read carefully.
[2]Breeding cover negatively impacted by fire, foraging use made of burned areas.

by fuel category for fire groups described for Montana forests (Fischer and Bradley 1987; Fischer and Clayton 1983). As indicated in figure 2, the variation of fuel loading and associated potential fire behavior within a group is probably large when compared to measurements between groups. When knowledge of potential fire behavior of a particular site is needed, site-specific fuel estimates or measurements must be made.

For broad-scale applications, physical properties such as loading may not be as important as fuel moisture and the condition of live vegetation to predict potential fire behavior. These are largely related to elevation, aspect, and season (Brown and Bevins 1986). Habitat types, and therefore fire groups, reflect elevation, aspect, and length of fire season. To this extent they may be useful for predicting fire behavior potential for a site.

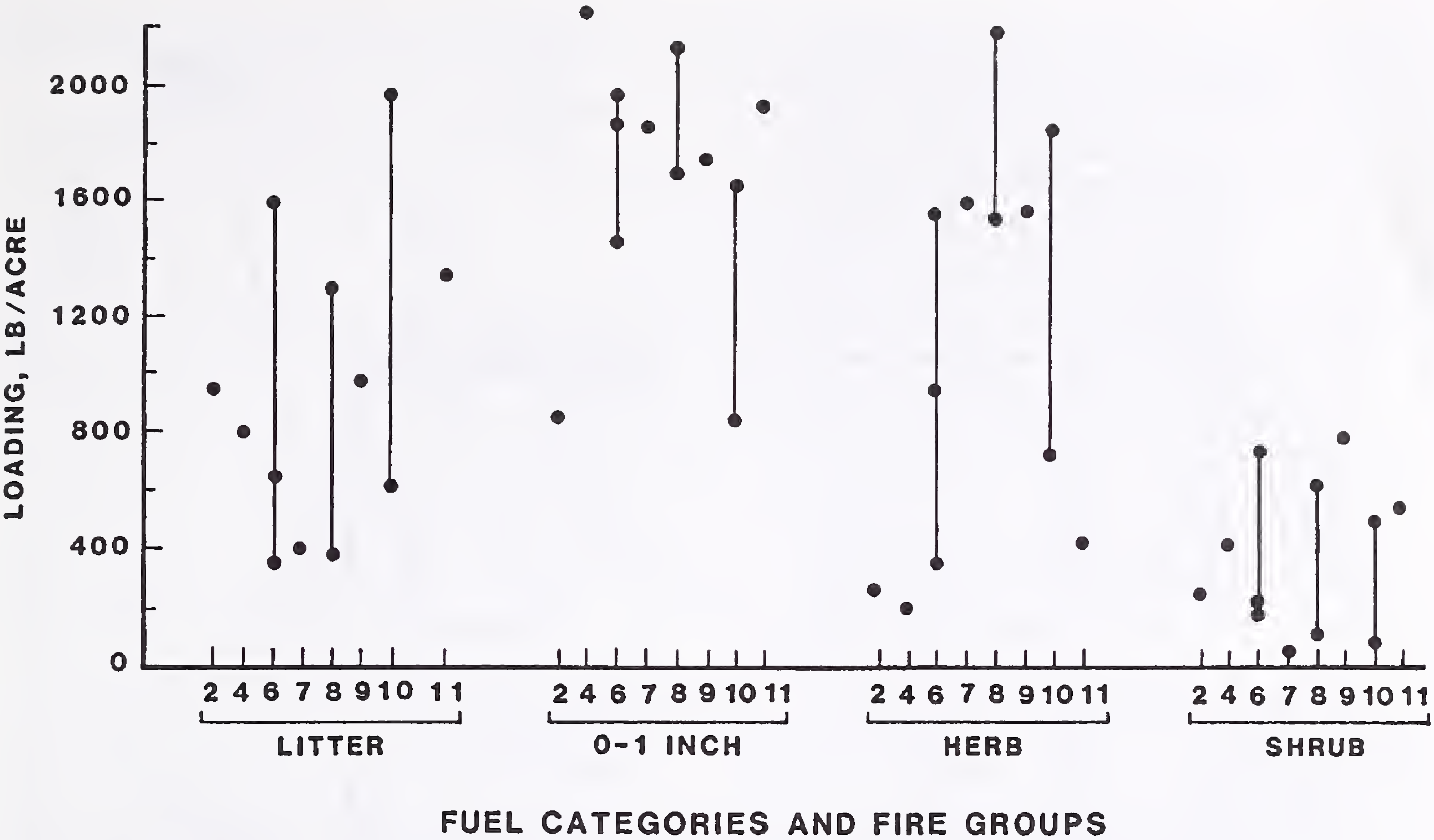

Figure 2—Fuel loading estimates for Montana Fire Groups. Plotted points represent mean fuel loading of selected fuel categories for fire groupings and locations. Fire Groups are represented by one to three locations. Numbers represent Montana Fire Groups (western Wyoming-southeastern Idaho Fire Groups roughly equivalent to these groups are in parentheses) as follows:

2—Warm, dry ponderosa pine habitat types (no equivalent)
4—Warm, dry Douglas-fir habitat types (some stands equivalent to those in FG 2)
6—Moist, Douglas-fir habitat types (FG 3)
7—Cool habitat types usually dominated by lodgepole pine (FG 5)
8—Dry, lower subalpine habitat types (FG 6)
9—Moist, lower subalpine habitat types (FG 7)
10—Cold, moist upper subalpine and timberline habitat types (FG 8)
11—Moist grand fir, western redcedar, and western hemlock habitat types (no equivalent).

Predicting Fire Mortality

Fire can damage trees in several ways: crown damage, including bud kill and foliage mortality, bole damage, cambial damage, and root damage (especially in shallow-rooted species). Mortality often results from the effects of a combination of fire-induced injuries.

Trees of different species and sizes vary in their resistance to fire damage. Tall trees are more likely to have a larger proportion of their foliage above scorch height and often have thicker bark, as well. Reinhardt and Ryan (1988) have developed a series of nomograms to relate tree characteristics and types of potential fire damage for several species of conifers. The nomograms help managers estimate tree mortality after prescribed underburning. The nomogram shown in figure 3 is used as follows:

To use the mortality nomogram, choose an acceptable level of mortality (e.g. 20 percent or a 0.2 probability of mortality). Acceptable mortality will depend on the value of the trees and the objectives of the fire. Successful underburning involves choosing and staying within a reasonable level of mortality.... Once an acceptable level of mortality has been chosen for a particular species, the nomogram can be used to develop a burning prescription.... Consider a shelterwood harvest with Douglas-fir leave trees averaging 17 inches (43.2 cm) in diameter, 100 ft (13.1 m) tall, with a crown ratio of 0.5. Entering the nomogram at the lower left at observed tree diameter, draw a horizontal line until you intersect the correct species line. Then turn a right angle and draw a line straight up. When the line crosses the top edge of the lower left box, bark thickness can be read, if desired, but it is not necessary to do so. In this example, bark thickness of a 17-in (43.2 cm)

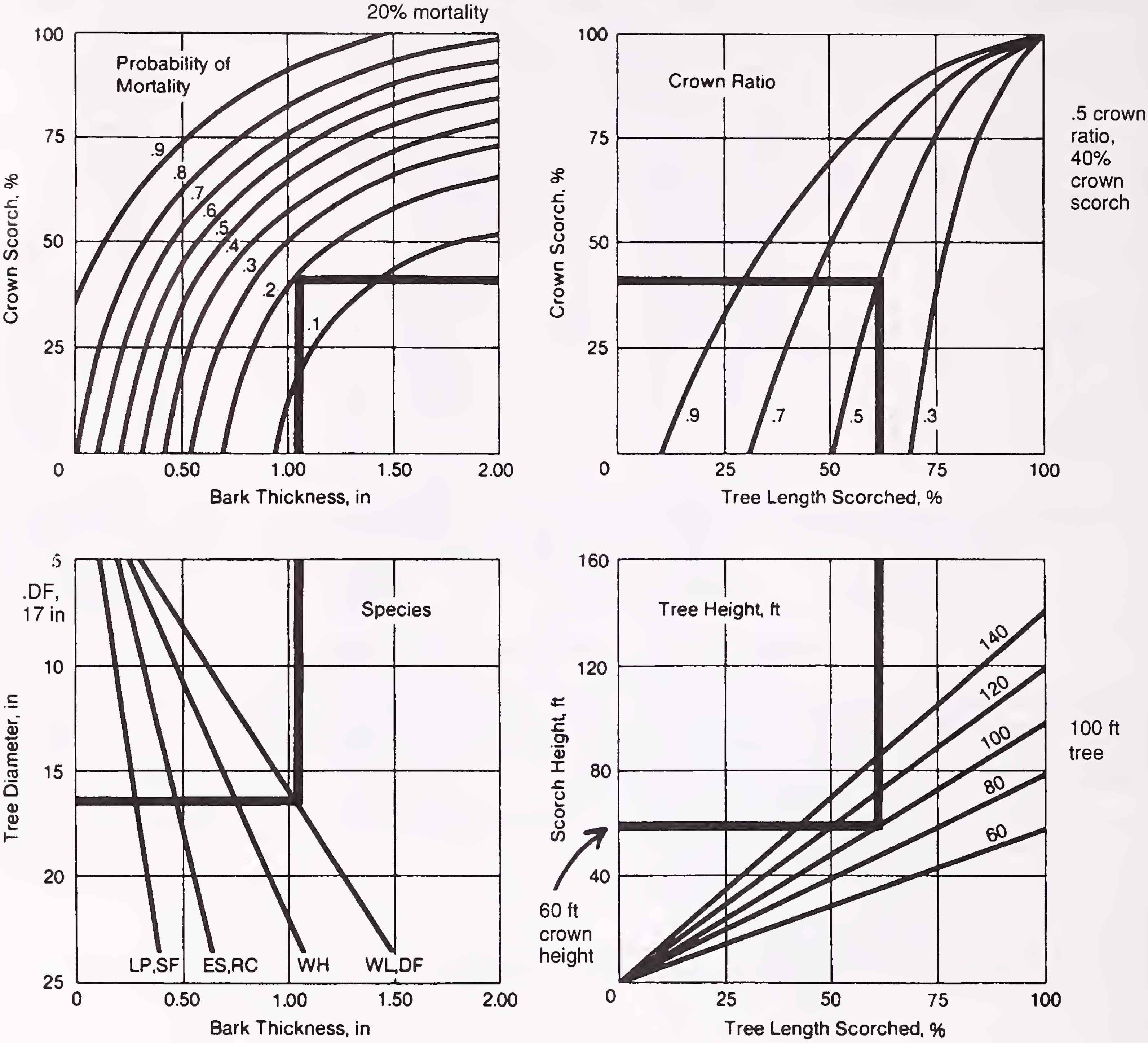

Figure 3—Nomogram to estimate tree mortality after prescribed underburning (Reinhardt and Ryan 1988). See text for a description of its use.

Douglas-fir is seen to be about 1.1 inches (2.8 cm). Continue the line straight up until it intersects the target mortality rate curve (0.2). At this point, turn a right angle again, to the right. This time, when passing from the upper left to the upper right quadrant, it is possible to read off crown volume scorched (percent). This example shows that a little more than 40 percent of the crown volume of these trees may be scorched without exceeding the target mortality of 20 percent.

The original document should be referred to for further instruction.

Crown Scorch and Insect Attack

Care must be taken when burning in forest stands to prevent or minimize scorching the crowns of residual overstory trees. Heavy fuel accumulations or slash concentrated near the base of overstory trees may require scattering or other treatment to avoid lethal cambium heating. Excessive crown scorch, cambium damage, or both can result in loss of vigor and increased susceptibility to bark beetle attack or tree mortality. For example, the relationships between crown defoliation and mortality caused by the

western pine beetle in ponderosa pine has been generalized as follows (Stevens and Hall 1960):

Percentage defoliation	Percentage of trees killed by beetles
0 - 25	0 - 15
25 - 50	13 - 14
50 - 75	19 - 42
75 - 100	45 - 87

The season in which a fire occurs is an important factor influencing tree mortality and the occurrence, duration, and severity of a potential beetle attack on fire-weakened trees. The result of crown scorching is usually more severe during the active growth period early in the summer than later when growth has slowed, terminal buds have formed, and a food reserve is being accumulated (Wagener 1955, 1961). Likewise, crown scorching that occurs in early spring, before or immediately after bud burst, often results in minimum damage to the tree.

Prescribed burning of understory vegetation and dead surface fuels can be carried out without serious threat of subsequent damage by bark beetles if the overstory trees are not severely scorched (Fischer 1980). If accidental scorching does occur, and bark beetle activity is detected, prompt removal of the severely scorched trees will reduce the probability of subsequent damage to healthy green trees. If scorching occurs outside the active growth period, scorched trees may recover and regain lost vigor. This may take 3 years, but signs of recovery should be visible during the first growing season that follows scorching.

Frequency of Burning

The consequences of too frequent fire on forest sites may include loss of seed source or regenerating roots and rhizomes, loss of nutrients, and a decline in the fertility of the site. Suppression of fire can result in hazardous fuel loadings, lack of regeneration, lowered understory and overstory diversity, and stand decadence. As a result, it seems prudent to gear the frequency of prescribed fire on a site to the wildfire frequencies that existed prior to organized fire suppression (Arno 1980).

Large Woody Debris

Fire is frequently used to reduce woody fuel buildup on forest sites. Fire plays an important role in recycling nutrients locked up in dead plant materials, especially in cold, dry environments where decay takes place very slowly. Nevertheless, a burning prescription should never be written so as to remove all woody debris from a site. Organic matter in the soil releases nutrients and enhances aeration and water retention. Rotting wood that results from the decay of large logs acts as a reservoir for mycorrhizae and nitrogen-fixing bacteria, which can reinoculate the site after fire or other disturbance. The importance of woody debris increases on droughty or otherwise harsh sites. Harvey and others (1987) recommend leaving between 11 and 16 tons/acre (24 and 36 metric tons/hectare) to retain productivity on forest sites.

Scattered large logs left on a site also retard soil movement and provide shade for young seedlings. The more tolerant tree species such as subalpine fir or Engelmann spruce will not successfully regenerate without at least partial shade. In addition, only as much mineral soil should be bared as is necessary to obtain desired stocking. On the other hand, quantities of organic matter in excess of the above requirements can be considered undesirable, especially on dry sites. Excess buildup of fuels can set the stage for high-intensity wildfires that critically reduce soil organic reserves.

A final reason for leaving moderate amounts of large-diameter woody debris scattered on the site following logging and burning is to supply food and cover for wildlife. Many small forest mammals rely on forest floor debris for cover and nesting sites. Rotten logs are often important foraging sites for both mammals and birds. Logs, for example, are important feeding sites for pileated woodpeckers.

Woodpeckers and other cavity-nesting birds (and mammals) also require snags, preferably scattered patches of snags, for nesting sites (McClelland and Frissell 1975; McClelland and others 1979).

The need to retain moderate amounts of scattered large-diameter woody debris should not preclude slash disposal. On most sites, untreated logging slash raises the fire hazard significantly higher than the pretreatment situation. This increased hazard will exist for at least 3 to 5 years, even with a maximum compaction effect from winter snows.

Logging slash, as well as large accumulations of deadfall in untreated stands, can affect elk behavior and movement. Elk use may diminish when slash inside a treatment unit exceeds 1.5 ft (0.5 m) in depth, and dead and down material outside the opening exceeds 1.5 ft (0.5 m) (Boss and others 1983).

Heat Effects on Soil

Properly applied, prescribed fire seldom causes long-term damage to the fertility of the most common western soils. The effect on naturally infertile soils is, however, unclear and should be monitored. The intense heat and ashes resulting from burning bulldozer-piled slash can affect regeneration success on the area occupied by the piles. Size of piles should be kept small, and burning should be deferred to periods of relatively high fuel and soil moisture (Holdorf 1982).

Prescribed Fire Planning

From a fire management perspective, a successful prescribed fire is one that is executed safely, burns under control, accomplishes the prescribed treatment, and attains the land and resource management objectives for the area involved. Successful prescribed burning requires planning. Such planning should be based on the following factors (Fischer 1978):

1. Physical and biological characteristics of the site to be treated.
2. Land and resource management objectives for the site to be treated.
3. Known relationships between preburn environmental factors, expected fire behavior, and probable fire effects.
4. The existing art and science of applying fire to a site.
5. Previous experience from similar treatments on similar sites.

FIRE GROUP ZERO: MISCELLANEOUS SPECIAL HABITATS

Group Zero is a miscellaneous collection of habitats that neither form a widespread vegetative zone nor fit into coniferous habitat type classifications.

Scree

The term "scree" refers to slopes covered with loose rock fragments, usually lying near the maximum possible angle of repose so that any disturbance causes minor rock slides down the face of the slope. Scree slopes may be treeless or they may support scattered trees with sparse undergrowth. Usually scree communities are regarded as special environments where the vegetation is in an uneasy equilibrium with the unstable substrate.

The discontinuous fuel often makes scree slopes unburnable. Individual trees or islands of vegetation may ignite, but fire spread is limited. A severe wind-driven fire could pass over the intervening open spaces and destroy a scree community, but this rarely happens. Due to the harsh environment, these sites do not revegetate well, and revegetation following a fire can take a long time.

Forested Rock

Forested rock is usually a steep canyon wall or mountainside composed of rock outcrops, cliffs, and occasional clumps of trees clinging to ledges and crevices. Forested rock is especially prominent along canyons and in rugged upper subalpine areas near timberline. These sites bear a certain similarity to scree sites, but the substrate is solid and climax species frequently become established.

Surface fires do not burn well because of the vertical and horizontal discontinuity of ground fuels. The probability of crown fires depends on the density and arrangement of trees on the rock face. In some cases the islands of vegetation are so widely scattered as to be almost immune to wildfire. In other cases, a continuity of foliage from the base to the top of a cliff can occur. Each tree forms a ladder into the lower branches of the next higher tree upslope. In such cases crown fires can occur over ground that would not support a less severe surface fire.

Revegetation of rocky sites proceeds at a rate characteristic of the site and depends on the severity of the fire, the age and depth of the soil on ledges and in pockets of rock, erosion, and the availability of seeds.

Wet Meadow

A meadow is an opening in the forest that is characterized by herbaceous vegetation and abundant moisture. Subirrigation is common during at least some part of the growing season. Mountain meadows are frequently too wet to burn during the fire season. In midsummer, larger wet meadows often act as natural firebreaks, but during the late summer and early fall they may carry grass fires. In some situations, especially when meadows are dominated by grass, they may burn early in the spring, following snowmelt and prior to greenup.

Streamside meadows may gradually become drier in the course of succession from a hydric to a mesic condition. The buildup of organic material and trapped sediments from the flowing water, combined with a possible deepening of the streambed and lowering of the water table, can leave former meadows in an intermediate condition between wet meadow and grassland. In some such sites the meadow becomes bordered by fire-maintained grassland. Fire suppression has allowed conifers to invade meadows where they would not normally be found.

Mountain Grassland

A mountain grassland (or grassy bald) is a grass-covered opening within an otherwise continuous coniferous forest. Mountain grasslands may act as firebreaks and can be maintained as grassland by light fires, but usually their fire ecology is less obvious. In the Bighorn Mountains of Wyoming, Despain (1973) found boundaries between grassland and forest, which he attributed to topography and soils. Daubenmire (1943) suggested that soil

factors might cause permanent mountain grasslands. It is also possible that these are natural grasslands that have little potential for forest development. Caution is indicated in management of stands adjacent to mountain grasslands until conditions responsible for their perpetuation are determined.

Deciduous Riparian Communities

Deciduous riparian communities are composed of sites dominated by deciduous trees, shrubs, or herbaceous vegetation adjacent to seasonal or perennial free-flowing streams, or open bodies of water. Such communities are often found in a narrow strip along drainage bottoms or between streambeds and upland forest vegetation. Overstory dominants include narrowleaf cottonwood, willows, dogwood, thinleaf alder, or other shrubs (Youngblood and others 1985). The herbaceous component may be lush and includes a diverse assemblage of forb and graminoid species.

The effects of fire in these communities have been little studied. Although riparian communities are productive and frequently have large amounts of live and dead woody fuels, moist conditions reduce the chance of fires spreading during much of the year. Leaf litter decomposes more rapidly than conifer needles, and dry fine fuels may be relatively scarce. Because these areas are often highly productive, they have the potential to support high-intensity fires when fine fuels are dry, especially during periods of high winds. Such severe fires destroy trees and top-kill shrubs. Reinvasion of burned areas should take place soon after fire because of the moist soil conditions. Many species, such as willow, are able to resprout after top removal. Cottonwood, willow, alder, and maple have airborne seeds that can invade from considerable distance. Some upland species, particularly spruce and aspen, may intermingle with riparian vegetation. The fire ecology of moist sites dominated by conifers is described in Fire Group Seven; aspen is discussed in Fire Group Four.

FIRE GROUP ONE: LIMBER PINE HABITAT TYPES

Habitat Types, Phases

Pinus flexilis/Cercocarpus ledifolius h.t. (PIFL/CELE), limber pine/curlleaf mountain-mahogany
Pinus flexilis/Festuca idahoensis h.t.-*Festuca idahoensis* phase (PIFL/FEID-FEID), limber pine/Idaho fescue-Idaho fescue phase
Pinus flexilis/Hesperochloa kingii h.t. (PIFL/HEKI), limber pine/spike fescue
Pinus flexilis/Juniperus communis h.t. (PIFL/JUCO), limber pine/common juniper

Vegetation

Fire Group One consists of limber pine habitat types. Limber pine or limber pine together with Douglas-fir dominate these sites. Lodgepole pine, subalpine fir, and aspen may be minor seral associates. Fire Group One habitat types may be found between 6,000 and 10,000 ft (1,829 and 3,048 m). They occur on drier sites adjacent to forests of Douglas-fir, lodgepole pine, subalpine fir, and Engelmann spruce. Limber pine habitat types may also form the forest ecotone with sagebrush steppe vegetation. Limber pine and Douglas-fir dominance on sites in close proximity to other conifers may indicate the presence of calcareous parent materials.

The distribution of limber pine is strongly affected by its dependence on animal-mediated seed dispersal. The seed of limber pine is dispersed chiefly by the Clark's nutcracker (Lanner 1980). The birds collect and cache the seed for future consumption. They frequently choose open or treeless areas as caching sites. Seed that germinates from forgotten caches makes up the bulk of limber pine regeneration. Factors that affect nutcracker population size and distribution also affect limber pine regeneration.

Undergrowth vegetation in Fire Group One sites is sparse but diverse. At lower elevations, stands are often part of the forest/shrub steppe ecotone. Associated shrub species are *Artemisia tridentata*, *Juniperus communis*, *Potentilla fruticosa*, *Ribes cereum*, *Shepherdia canadensis*, and *Symphoricarpos oreophilus*. Undergrowth vegetation may be scant on rocky ridges. The most frequently associated graminoids are *Carex rossii*, *Festuca idahoensis*, *Hesperochloa kingii*, *Koeleria cristata*, *Melica bulbosa*, *Poa nervosa*, *Pseudoroegneria spicata* (*Agropyron spicatum*), and *Stipa occidentalis*. Forbs include *Achillea millefolium*, *Antennaria microphylla*, *Arnica cordifolia*, *Astragalus miser*, *Balsamorhiza sagittata*, *Campanula rotundifolia*, *Crepis accuminata*, *Cymopterus hendersonii*, *Fragaria virginiana*, *Linum perenne*, *Potentilla ovina*, and *Senecio streptanthifolius*.

Forest Fuels

For the most part, limber pine climax stands occur on sites where fire-sustaining fuels are light (fig. 4). Where greater shrub coverage occurs, such as the *Pinus flexilis/Cercocarpus ledifolius* habitat type, or where graminoids are able to attain good cover in the understory, the fire hazard may be somewhat higher. Otherwise, fuels are sparse and discontinuous.

The greatest fire hazard to Fire Group One stands is their proximity to more flammable vegetation. This may be dense forest vegetation or sagebrush steppe, either of which has heavier and more

Figure 4—Limber pine habitat types often occur on dry unproductive sites. Undergrowth is sparse on rocky sites (Bridger-Teton National Forest).

continuous fuel loads than Fire Group One. Greater flammability may be encountered where both limber pine and Douglas-fir share site dominance. Their higher site productivity makes fuel accumulation more likely. Douglas-fir with its denser, longer crown is also more flammable than the sparsely branched limber pine.

Downed woody fuel loadings in Montana limber pine stands ranges between 5 tons/acre (11.2 metric tons/hectare) and 15 tons/acre (33.6 metric tons/hectare) with about 80 percent of the loading accounted for by material greater than 3 inches (7.62 cm) in diameter (Fischer and Clayton 1983). Average loadings in Group One limber pine sites are probably similar. This material is often the result of fallen snags created by a previous fire. Such material is usually scattered about the site. Fires are most likely to carry on sites with good grass coverage.

Role of Fire

Limber pine stand dynamics are determined by climate and soil factors, special animal relations, and fire. Harsh growing conditions make stand colonization and development slow. Regeneration of limber pine is dependent on seed collection and subsequent caching by Clark's nutcrackers.

Fire intensity in limber pine habitat types usually remains low, and flames are unlikely to enter tree crowns even on sites where there is enough fine fuel available to carry a fire. The scattered distribution of the trees themselves inhibits fire spread. In Yellowstone National Park, Cooper (1975) believed that limber pine-Douglas-fir stands had "variable" fire frequencies. He noted six fire scars on old (>300 years) Douglas-fir associated with limber pine. Arno and Gruell (1983) reported a mean fire interval of 74 years for a southwestern Montana limber pine/bluebunch wheatgrass habitat type at a grassland ecotone. Keown (1977) also reported fairly lengthy fire-free intervals (about 100 years) in a similar Montana limber pine stand with grass and shrub understory.

Where Douglas-fir is a codominant with limber pine, fire maintains a mosaic of the two species. Frequent low fires may favor limber pine by keeping fuel loadings to a minimum and prevent the occurrence of tree-killing fire. Fire may favor limber pine over Douglas-fir in the smaller age classes (Keown 1977). As trees increase in diameter, susceptibility

to fire changes. Mature specimens of Douglas-fir are probably more fire-resistant than limber pine trees of similar diameter. Cooper (1975) noted that limber pine, unlike Douglas-fir, does not appear to accumulate multiple fire scars, indicating that it is unable to survive as many fires. Keown (1977) killed about 20 percent of the invading limber pines with low-severity spring fire in southwestern Montana. More severe fire killed 80 percent. Historic frequencies may have differed somewhat between habitat types, with grass-dominated types experiencing fires more often because of the greater availability of fine fuels. The relative importance of Douglas-fir and limber pine in late seral or climax stands is affected by fire frequency. More frequent moderate fires at this successional stage probably favor Douglas-fir because of its thick, fire-resistant bark.

Forest Succession

Douglas-fir is frequently codominant in Fire Group One. Limber pine climax stands often grade into the drier Douglas-fir habitat types such as *Pseudotsuga menziesii/Cerocarpus ledifolius* or *Pseudtosuga menziesii/Symphoricarpos oreophilus*. Stands with a large proportion of Douglas-fir may have a fire ecology more similar to these types, which is described in Fire Group Two. The hypothetical role of fire in Fire Group One stands is illustrated in figure 5 (subsequent letters in the text refer to this figure).

Limber pine stands are generally multiaged because of continual seed caching by Clark's nutcracker. The exception is where a stand is removed by fire or other disturbance. On many sites Douglas-fir may be a codominant. Its ability to recolonize a site depends on whether windborne seed is available from a nearby seed source. A lack of fuels makes a low to moderate fire of limited extent the most common type of burn in Group One stands regardless of their age structure. Stand-replacement fires may rarely occur, and the successional pathway here describes the developmental sequences after removal of the tree stratum. Any fire in trees in the youngest age class will return the site to a grass-dominated state (A). On moister sites, this may be followed rapidly by a shrub stage (B). Low fires in older age classes (C,D,E) will thin the trees and produce open patches of ground. Limber pine appears to become fire resistant at a younger age than Douglas-fir, so low fires occurring in the sapling stage may favor increased dominance by pine. Open

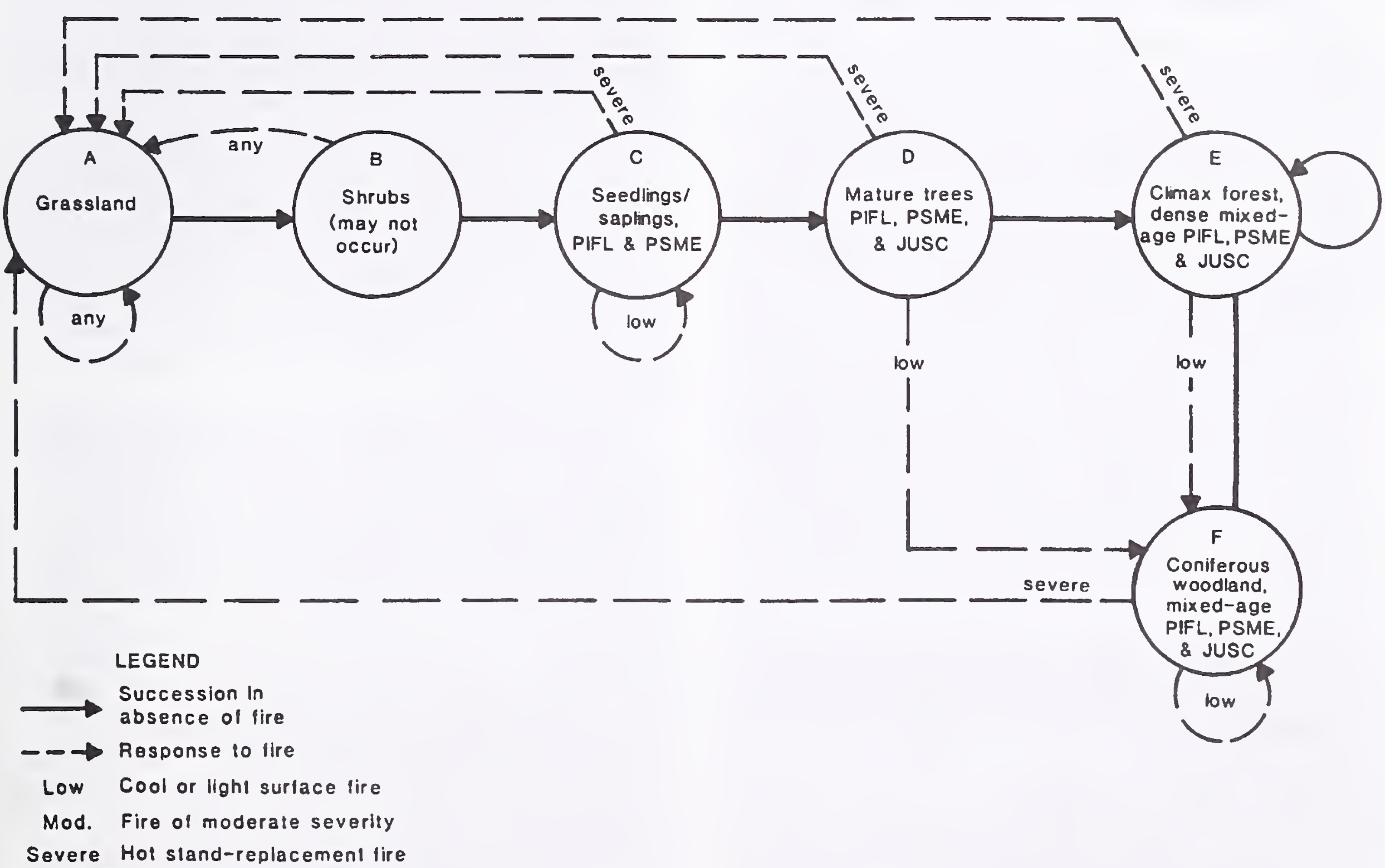

Figure 5—Hypothetical fire-related successional pathways for Fire Group One habitat types.

areas created by fire are attractive seed-caching sites for the Clark's nutcracker, and limber pine regeneration results (Lanner and Vander Wall 1980). By the time the majority of trees in the stand are mature, enough fuels may have built up to sustain a low to moderate fire. The resulting stand is a more open, mixed-age woodland (F). A similar stand results from low to moderate fires in the climax stage.

Stands at all ages are typically open with sufficient gaps where intolerant seedlings can establish. Exposed mineral soil makes good seedbed for limber pine or Douglas-fir. The relative success of the pine or Douglas-fir depends on seedling microsite conditions. Limber pine is better able to survive cold and dessication. Douglas-fir may have a competitive advantage on less harsh sites because of its more rapid growth rate. Even where Douglas-fir is able to reproduce successfully, however, it never attains much canopy coverage. Limber pine remains the dominant or codominant species at climax.

Achieving the mature or climax state takes several centuries. Climax, once attained, persists because of the low rate of disturbance and the longevity of the pines. Limber pine may reach 2,500 years of age (Ahlenslager 1987). Severe fires are very unlikely, but possible, in the mature or climax stages. They will recycle the stand to a shrub or herb condition (A).

Fire Management Considerations

Limber pine stands have limited wood products value. They may be used by deer as summering grounds, particularly where *Cercocarpus ledifolius* is vigorous and accessible. Limber pine seed provides a nutritious food source for birds, small mammals, and bears. Livestock use the stands for shade where foraging areas adjoin the stands. Limber pine cover can also provide important watershed protection (Mauk and Henderson 1984).

Although fire does not appear necessary to maintain most limber pine stands, periodic burning may benefit important understory forage species by removing decadent growth and stimulating resprouting (Steele and others 1983). The postfire regeneration of limber pine depends on seed-caching by Clark's nutcracker. Factors that affect the population size or distribution of nutcrackers will impact limber pine regeneration.

FIRE GROUP TWO: HABITAT TYPES SUPPORTING COOL, DRY DOUGLAS-FIR FORESTS

Habitat Types, Phases

Pseudotsuga menziesii/Arnica cordifolia h.t.-*Arnica cordifolia* phase (PSME/ARCO-ARCO), Douglas-fir/heartleaf arnica-heartleaf arnica phase

Pseudtosuga menziesii/Arnica cordifolia h.t.-*Astragalus miser* phase (PSME/ARCO-ASMI), Douglas-fir/heartleaf arnica-timber milkvetch phase

Pseudotsuga menziesii/Berberis repens h.t.-*Symphoricarpos oreophilus* phase (PSME/BERE-SYOR), Douglas-fir/Oregon-grape-mountain snowberry phase

Pseudotsuga menziesii/Cercocarpus ledifolius h.t. (PSME/CELE), Douglas-fir/curlleaf mountain-mahogany

Pseudotsuga menziesii/Festuca idahoensis h.t.-*Festuca idahoensis* phase (PSME/FEID-FEID), Douglas-fir/Idaho fescue-Idaho fecue phase

Pseudtosuga menziesii/Juniperus communis h.t. (PSME/JUCO), Douglas-fir/common juniper

Pseudotsuga menziesii/Symphoricarpos oreophilus h.t. (PSME/SYOR), Douglas-fir/mountain snowberry

Vegetation

Fire Group Two is composed of cool, dry, relatively unproductive Douglas-fir habitat types. Douglas-fir is often the climax species at the lowest forested elevations. It decreases to the east as base elevations become higher (Steele and others 1983). Soil, as well as temperature and moisture regime, influences the distribution and dominance of Douglas-fir. It is often able to out-compete other potential climax species on low- to mid-elevation sites with calcareous soils (Loope and Gruell 1973). On these sites, Douglas-fir and sometimes limber pine serve as the major seral species. Limber pine gains in importance in Douglas-fir stands east of the Absarokas and the crest of the Wind River Range (Crane 1982). Rocky Mountain juniper may be a seral species in Fire Group Two, the most open habitat types. Lodgepole pine is occasionally present on some noncalcareous sites. Moister sites, where lodgepole pine and aspen are important seral species, are described in Fire Group Three.

Fire Group Two stands remain scattered to open and do not develop dense overstory canopies. Undergrowth may be dominated by graminoids, low shrubs, or dense stands of taller shrubs as in the *Pseudotsuga menziesii/Cercocarpus ledifolius* habitat type (fig. 6). Regeneration of Douglas-fir is sporadic because of poor moisture conditions or shrub competition. Important shrubs or small trees are *Acer glabrum*, *Amelanchier alnifolia*, *Artemisia tridentata*, *Berberis repens*, *Cercocarpus ledifolius*, *Juniperus communis*, *Physocarpus malvaceous*, *Prunus virginiana*, *Ribes cereum*, *Rosa woodsii*, *Shepherdia canadensis*, *Spiraea betulifolia*, and *Symphoricarpos oreophilus*. Common graminoids are *Carex rossii*, *Elymus cinereus*, *Festuca idahoensis*, *Hesperochloa kingii*, *Poa nervosa*, and

Figure 6—Typically, Fire Group Two habitat types have open canopies. The understory is often made up of shrubs or grasses common in surrounding shrublands (Douglas-fir/curlleaf mountain-mahogany site, Caribou National Forest).

Pseudoroegneria spicata (*Agropyron spicatum*). Frequently encountered forbs are *Achillea millefolium*, *Antennaria microphylla*, *Arnica cordifolia*, *Astragalus miser*, *Balsamorhiza sagittata*, *Campamula rotundifolia*, *Crepis acuminata*, *Pyrola secunda*, *Senecio streptanthifolius*, and *Smilacina racemosa*.

Forest Fuels

Downed, dead, woody fuels are relatively light (fig. 7). The best available summarized data are from Montana. There, similar sites averaged about 13 tons/acre (29.1 metric tons/hectare) (Brown and See 1981). Twigs and small branchwood less than 3 inches (7.62 cm) in diameter are the predominant woody fuels on the forest floor. Regeneration is usually sparse. The combination of widely spaced, thick-barked trees and the characteristically depauperate undergrowth results in a low fire hazard for most open stands of old-growth Douglas-fir (Crane and Fischer 1986). Individual Douglas-fir trees will, however, often have branches close to the ground. If sufficient ground fuels are available, torching can occur.

Fires can become more extensive. In dry weather on the Yellowstone Plateau, individual trees torch and fire creeps through the understory vegetation, consuming litter and duff layers. Fire spreading into surrounding sagebrush will smolder and burn out. If drought persists from spring into summer, 1,000-hour fuel moistures may drop as low as 10 percent. Early curing of grasses may take place. Fires spread slowly, but are severe. When high winds occur, groups of trees crown out, and spotting up to one-fourth mile is common. Duff and litter layers are consumed to mineral soil and fire will spread rapidly through surrounding sagebrush and grass (Yellowstone 1991).

The large, dense witches'-brooms caused by dwarf mistletoe in Douglas-fir are often broken from the trees during snowstorms. These accumulate around the bases of the trees and increase the likelihood of torching from surface fires (Alexander and Hawksworth 1975). Large brooms on living or standing dead trees may promote crown fires and spot fires.

Role of Fire

Douglas-fir forests in Jackson Hole probably experienced fires about every 50 to 100 years (Loope and Gruell 1973). Douglas-fir adjacent to sagebrush steppe vegetation in both Jackson Hole and the valleys of northern Yellowstone appear to have shorter fire-free intervals. Houston (1973) reported intervals of 20 to 25 years in the Lamar, Gardner, and Yellowstone valleys over the past 300 to 400 years. In forest ecotonal sites, fine fuel loads closely resemble the sagebrush steppe because trees are widely scattered. As trees become more dense, the undergrowth becomes sparse, fine fuel loads are reduced, and fire potential lessened.

Open stands in Fire Group Two should generally sustain low thinning fires. Only when very low fuel moistures and high winds coincide are crown fires a concern. Fuel discontinuity in open, dry, shrubby habitat types such as *Pseudotsuga menziesii/Cercocarpus ledifolius* should lower fire frequency. Dry soils or otherwise poor stocking conditions slow the influx of conifers during fire-free intervals.

Fire can open stands and rejuvenate sprouting shrubs. Fire favors vigorously resprouting species over those that resprout poorly, such as curlleaf

Figure 7—Down and dead fuel loads in Fire Group Two sites are light. There may be abundant herbaceous or shrub live fuels, but because tree densities are low, large woody fuels are sparse (Douglas-fir/curlleaf mountain-mahogany site, Caribou National Forest).

mountain-mahogany, *Cercocarpus ledifolius* (Gruell 1986). Although curlleaf is sensitive to fire damage, it is still dependent on fire to provide suitable conditions for reproduction. Arno and Wilson (1986) found in their central Idaho study areas that

> ...frequent wildfires prior to 1900 kept mountain mahogany largely confined to extremely rocky sites where fuel was sparse. Absence of fire during the past century on many sites allowed the species to increase in abundance. However, mountain-mahogany is becoming decadent on many sites and seems unable to compete with associated conifers.

Forest Succession

In Fire Group Two, Douglas-fir is generally the dominant species throughout succession. Figure 8 illustrates the hypothetical role of fire for these sites. Subsequent letters in text refer to figure 8.

In this Fire Group, sites are generally open, with discontinuous fuels. Severe fires are very infrequent unless they originate in neighboring, more productive stands. Following a stand-replacing fire, resprouting shrubs and herbaceous vegetation dominate the site, possibly for a long time. Given an adequate seed source and good seedbed conditions, Douglas-fir and, on some sites, limber pine seedlings follow (B). Any fire from this state until the pole stage will most likely cause the stand to revert to shrub and herb vegetation. A few limber pine saplings may survive low fire. Pole-sized Douglas-fir may tolerate low to possibly low-moderate fires. Stands are further opened by these fires, and in the canopy openings, shrubs, herbs and more Douglas-fir seedlings will establish (C1). Without fire, a mature stand of Douglas-fir develops, with young Douglas-fir in the understory (D). Low fires thin smaller trees and create mineral seedbed conditions. Moderate fires may remove the understory but are unlikely to kill large overstory trees. The result of a moderate fire is a more open, parklike stand of mature trees (D1). A climax stand may contain several age classes of trees and is maintained by low and moderate fires. In the unlikely event of a severe fire, the stand will return to the initial treeless condition (A).

Fire Management Considerations

Fire uses in Group Two stands include sanitation, preparing seedbed, controlling of species composition, managing fuels at recreation sites, improving wildlife habitat, and enhancing esthetic values.

In the absence of fire, hazardous fuel situations can develop in some stands. A combination of decadent shrubs, accumulated deadfall, litter, and other debris can produce fires severe enough to scorch the crowns and kill the cambium of overstory trees.

Fire may be used to reduce the susceptibility of Douglas-fir stands to western spruce budworm. In the Northern Rockies, the increased duration and severity of western spruce budworm outbreaks in the last several decades appears to be associated with the decrease in fire extent, which began with the advent of effective fire suppression. On drier sites where Douglas-fir forms multistoried stands, the potential for an intensive budworm attack is much greater. A high density of Douglas-fir increases the chance that budworms migrating downward from the canopy will land in other suitable host trees. Where stands are open, migrating budworms will land instead on the ground where they may desicate, starve, or be eaten by various predators (Anderson and others 1987; Carlson and Wulf 1989; Fellin and others 1983).

Habitat types in this fire group have generally low potential for timber production. Low site index, stocking limitations, and steep slopes make these sites more valuble for other uses. Where regeneration of Douglas-fir is a concern, some shading will protect seedlings and reduce the cover of competitive shrubs. Low fires that do not top-kill tall shrubs and scarification without burning are better options where shrub competition is a problem (Steele 1988).

Big-game winter and spring range can be rejuvenated with properly applied prescribed fire. Such fires can reduce encroachment of Douglas-fir, remove accumulated dead plant materials, recycle nutrients, regenerate mature and decadent shrubs, and increase distribution and production of nutrient-rich grasses and forbs. Fire can increase berry production in black bear habitat (Irwin and Hammond 1985). Prescribed fire can be used to increase the nutritional

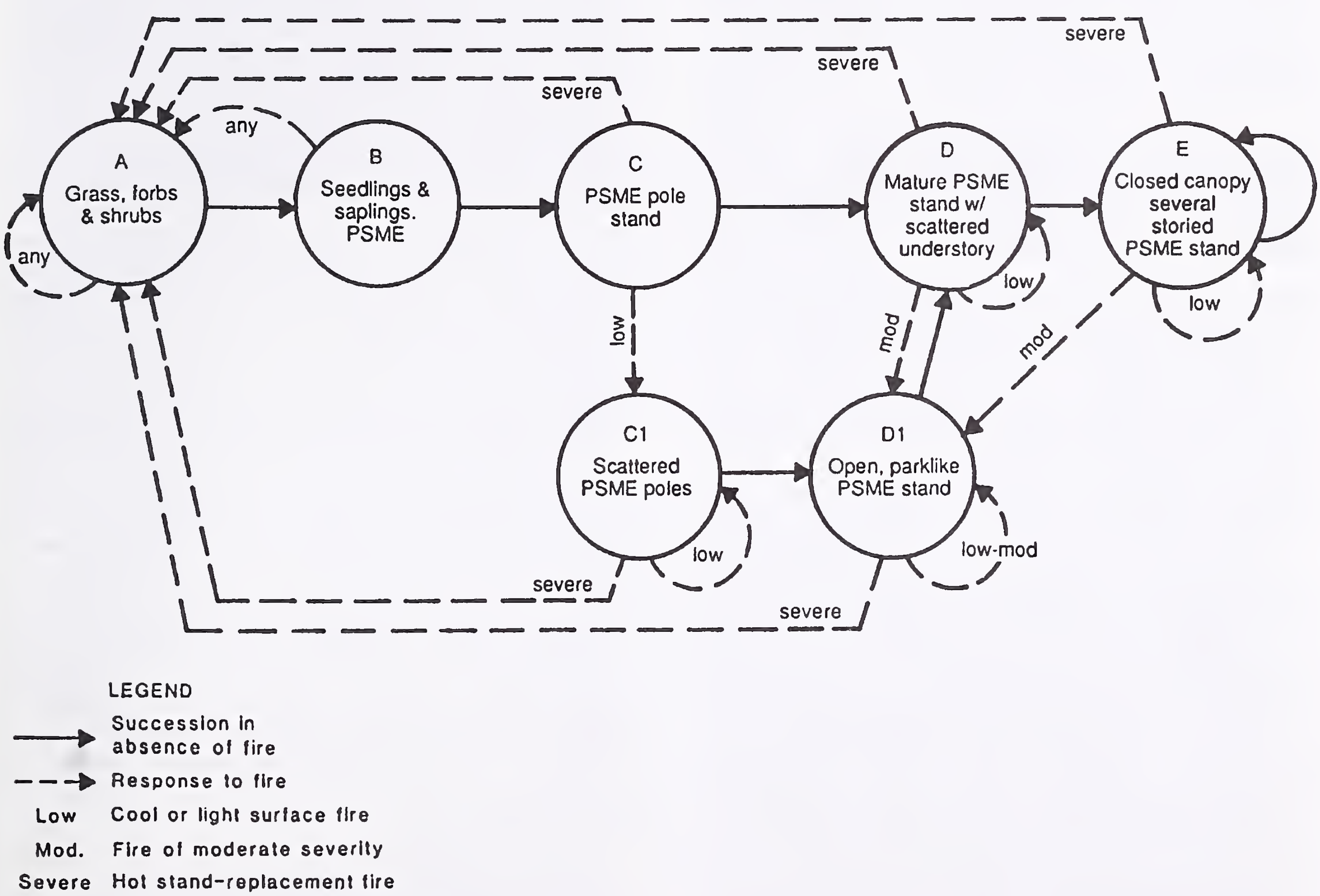

Figure 8—Hypothetical fire-related successional pathways for Fire Group Two habitat types.

value of critical wintering and fawning habitat, and thereby reduce neonatal fawn losses of mule deer (Schneegas and Bumstead 1977).

Grazing can accelerate succession to conifers in Douglas-fir stands by reducing the cover of competing understory plants, exposing favorable seedbed, and eliminating fine fuels that carry thinning fires (Zimmerman and Neuenschwander 1984).

The use of fire to improve forage production on some Group Two sites may be difficult because the sparse undergrowth may not carry fire. Caution is warranted if timber milkvetch (*Astragalus miser*) is present on grazing areas. This plant is poisonous to sheep and cattle and is highly resistant to fire damage. It can send up shoots from the surviving taproot and set seed the first year following fire. If much mineral soil has been exposed, a good crop of seedlings is usually produced and the population of this species may greatly increase (McLean 1969).

A guide to prescribed fire opportunites in grasslands invaded by Douglas-fir has been prepared by Gruell and others (1986). Although the specific study location was in Montana, the basic priniciples and guidelines presented are generally applicable to other dry Douglas-fir sites as well. Managers who are interested in using fire to enhance productivity of grassland or shrubland where Douglas-fir encroachment is a problem may wish to refer to this publication.

FIRE GROUP THREE: MOIST DOUGLAS-FIR HABITAT TYPES

Habitat Types, Phases

Pseudotsuga menziesii/Acer glabrum h.t.-*Pachistima myrsinites* phase (PSME/ACGL-PAMY), Douglas-fir/Rocky Mountain maple-pachistima phase

Pseudotsuga menziesii/Berberis repens h.t.-*Carex geyeri* phase (PSME/BERE-CAGE), Douglas-fir/Oregon-grape-elk sedge phase

Pseudotsuga menziesii/Berberis repens h.t.-*Juniperus communis* phase (PSME/BERE-JUCO), Douglas-fir/Oregon-grape-common juniper phase

Pseudotsuga menziesii/Berberis repens h.t.-*Berberis repens* phase (PSME/BERE-BERE), Douglas-fir/Oregon-grape-Oregon-grape phase

Psuedotsuga menziesii/Calamagrostis rubescens h.t.-*Pachistima myrsinites* phase (PSME/CARU-PAMY), Douglas-fir/pinegrass-pachistima phase

Pseudotsuga menziesii/Calamagrostis rubescens h.t.-*Calamagrostis rubescens* phase (PSME/CARU-CARU), Douglas-fir/pinegrass-pinegrass phase

Pseudotsuga menziesii/Osmorhiza chilensis h.t. (PSME/OSCH), Douglas-fir/mountain sweetroot

Pseudotsuga menziesii/Physocarpus malvaceous h.t.-*Pachistima myrsinites* phase (PSME/PHMA-PAMY), Douglas-fir/ninebark-pachistima phase

Pseudotsuga menziesii/Physocarpus malvaceous h.t.-*Pseudotsuga menziesii* phase (PSME/PHMA-PSME), Douglas-fir/ninebark-Douglas-fir-phase

Pseudotsuga menziesii/Physocarpus monogynus h.t. (PSME/PHMO), Douglas-fir/mountain ninebark

Pseudotsuga menziesii/Spiraea betulifolia h.t.-*Calamagrostis rubescens* phase (PSME/SPBE-CARU), Douglas-fir/white spirea-pinegrass phase

Pseudotsuga menziesii/Spiraea betulifolia h.t.-*Spiraea betulifolia* phase (PSME/SPBE-SPBE), Douglas-fir/white spirea-white spirea phase

Pseudotsuga menziesii/Symphoricarpos albus h.t.-*Symphoricarpos albus* phase (PSME/SYAL-SYAL), Douglas-fir/common snowberry-common snowberry phase

Pseudotsuga menziesii/Vaccinium globulare h.t.-*Vaccinium globulare* phase (PSME/VAGL-VAGL), Douglas-fir/blue huckleberry-blue huckleberry phase

Vegetation

Fire Group Three consists of relatively moist Douglas-fir habitat types where lodgepole pine, aspen, or Douglas-fir are major seral species (fig. 9). Fire Group Three habitat types occur on cooler or moist exposures between 5,700 and 8,500 ft (1,737 and 2,590 m). Limber pine may occur in small amounts on drier microsites within the group.

Shrubs of several species are dominant members of the undergrowth in many Group Three habitat types. In others, graminoids may be important, especially after a stand is disturbed. Dominant shrubs in this Fire Group include *Acer glabrum*, *Amelanchier alnifolia*, *Berberis repens*, *Juniperus communis*, *Pachistima myrsinites*, *Physocarpus malvaceous*, *Prunus virginiana*, *Ribes viscosissimum*, *Shepherdia canadensis*, *Spiraea betulifolia*, *Symphoricarpos albus*, and *Symphoricarpos oreophilus*. *Calamagrostis rubescens*, *Carex geyeri*, *Carex rossii*, *Elymus glaucus*, and *Poa nervosa* are graminoids that are often present. Forbs occuring in these stands include species such as *Achillea millefolium*, *Arnica cordifolia*, *Aster conspicuus*, *Astragalus miser*, *Disporum trachycaulum*, *Fragaria vesca*, *Geranium viscosissimum*, *Goodyera oblongifolia*, *Osmorhiza chilensis*, *Pyrola secunda*, *Smilacina racemosa*, *Thalictum fendleri*, and *Thalictrum occidentalis*.

Forest Fuels

In comparable Montana Douglas-fir stands, downed fuel loads averaged about 13 tons/acre

Figure 9—An open, moist Douglas-fir/snowberry stand (Yellowstone National Park).

(29 metric tons/hectare) with some stands having considerably heavier loadings. Closed stands with dense Douglas-fir understories present the highest fire hazard. Stands may have relatively large amounts of downed twigs and small branchwood. Downed as well as standing dead trees killed by dwarf mistletoe may add greatly to fuel loads and corresponding fire hazard (fig. 10). If dense understories are absent, fire hazard is reduced accordingly; however, the dense overstory trees and the presence of dead branches near the ground create a crown fire potential under severe burning conditions. Fuel conditions in stands dominated by either lodgepole pine or aspen are less hazardous than in those dominated by Douglas-fir. Laddered fuels are less prevalent, and there is less probability of fire moving from the forest floor to the crown (Crane and Fischer 1986; Fischer and Clayton 1983).

Role of Fire

Fire regimes of Douglas-fir and lodgepole pine forests are variable over their distribution (Kilgore 1981). Topography, weather, stand structure, and fuel loading all contribute to different patterns of fire intensity and frequency in these stands. A complete range of fire behavior is represented in this type, from light surface fires to stand-replacement fires. A mosaic of fire treatments probably occurred across the historical landscape, with much variability also existing within a single fire treatment (Arno 1980). Stands are thinned or replaced, and the potential dominance of one species over another altered. Low or thinning fires favor Douglas-fir because mature trees are fairly fire resistant. Seedlings are able to establish in moderate amounts of residual duff and are relatively shade tolerant. Stand-replacement fires favor seral lodgepole pine or aspen on sites where seeds or suckering roots are available. The success of aspen regeneration depends partly on severity of the fire. A high-severity burn may retard or reduce suckering if shallow roots are exposed to lethal heating. Large coverages of aspen, lodgepole pine, *Shepherdia canadensis*, *Ceanothus velutinus*, or *Calamagrostis rubescens* may indicate a recent history of severe or repeated burning (Steele and others 1983). On some habitat types in this Fire Group, shrubs have the potential to dominate stands if fire removes the Douglas-fir overstory (fig. 11).

Habitat types in this fire group are more moist and provide more favorable regeneration conditions than those in Fire Group Two, and succession may proceed more quickly.

Arno (1980) reported a mean fire-free interval of 15 to 30 years for the Douglas-fir series in the Northern Rocky Mountains. Houston (1973) estimated a presettlement fire frequency of 20 to 25 years for the conifer/sagebrush steppe vegetation in northern Yellowstone Park. In the Jackson Hole area, Loope and Gruell (1973) estimated a fire frequency between 50 and 100 years for lower elevation conifer forests, which, although moister, appear to be reasonably comparable with those in Houston's study. They estimated a fire frequency of 25 to 100 years for a Douglas-fir forest with seral aspen on Blacktail Butte in Grand Teton National Park. In western Montana, *Psuedotsuga menziesii/Physocarpus malvaceous* and *Psuedotsuga menziesii/Vaccinium globulare* stands had mean fire-free intervals of 15.8 years (Crane and others 1983). In southwestern Montana, stands of Douglas-fir (mostly *Pseudotsuga menziesii/Calamagrostis rubescens* and *Pseudotsuga menziesii/Festuca idahoensis*) on the ecotone between forest and

Figure 10—In this Douglas-fir/blue huckleberry stand, seral lodgepole pine stand is being replaced by climax Douglas-fir. As lodgepole pine falls, it creates heavier downed woody fuel loads, increasing the fire hazard (Targhee National Forest).

Figure 11—Shrubs are an important part of the undergrowth in some Fire Group Three habitat types. Fire or other disturbance may release shrubs, giving them the potential to dominate stands (Douglas-fir/ninebark, Caribou National Forest).

sagebrush-grassland had presettlement fire-free intervals of 35 to 40 years (Arno and Gruell 1983). In another Montana study, a lack of fire since 1890 allowed extensive stands of Douglas-fir to invade grassland where fires occurring every few decades formerly restricted conifers to rocky outcrops. A combination of fire suppression, grazing (which reduced fine fuels), and a cessation of ignitions by Native Americans was believed to be responsible for the reduction in fire occurrence (Arno and Gruell 1986).

Forest Succession

Hypothetical successional pathways illustrated in figure 12 show probable succession to Douglas-fir climax where lodgepole pine (fig. 12A) or aspen (fig. 12B) are the major seral species.

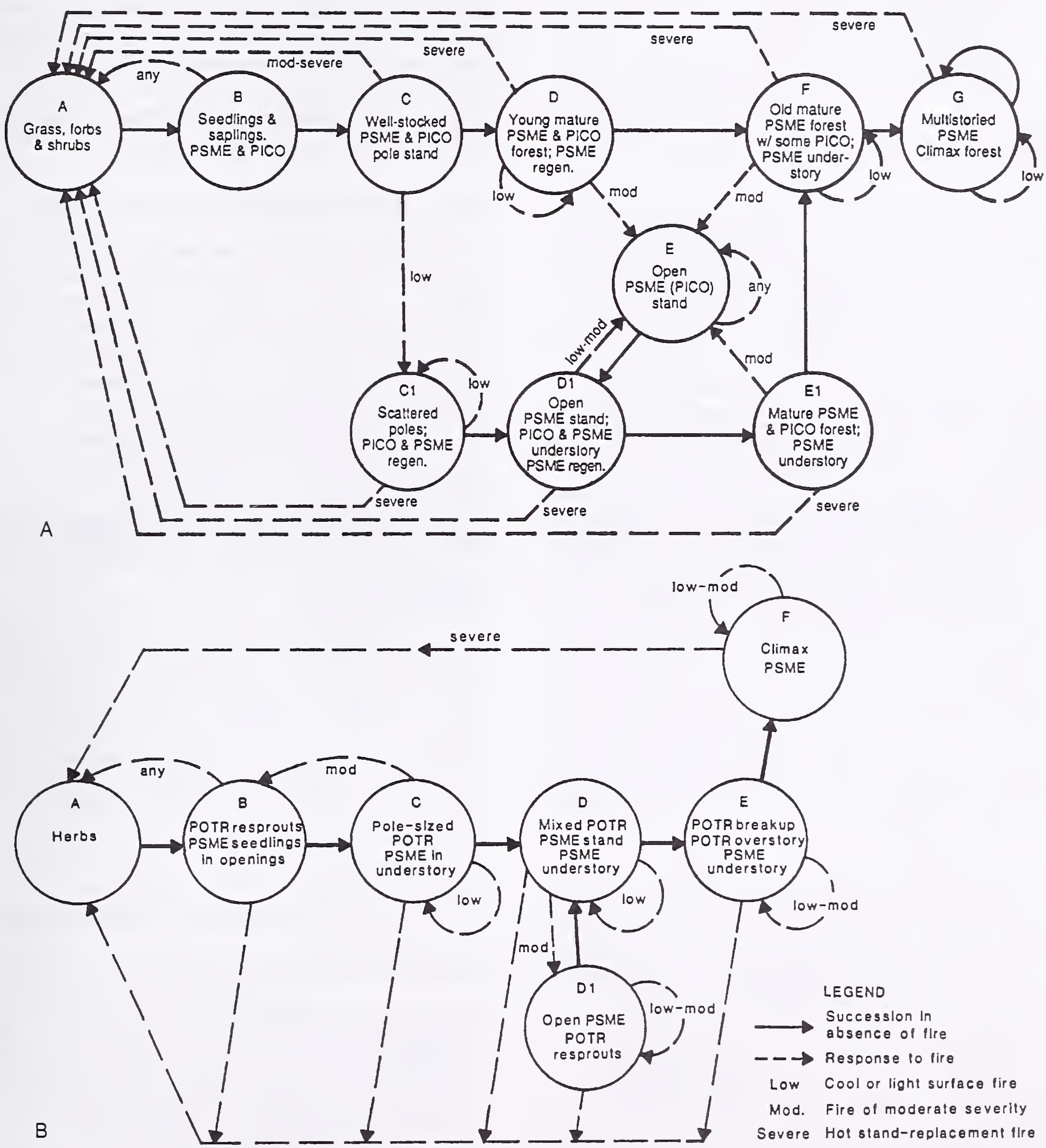

Figure 12—Hypothetical fire-related successional pathways for Fire Group Three habitat types: (A) succession with lodgepole, (B) succession with aspen.

Succession With Lodgepole Pine—Where lodgepole pine and Douglas-fir are seral (fig. 12A), a stand of herbs and shrubs follows stand-replacement fires (A). Repeated fires maintain the treeless condition. Conifer seedlings and saplings soon dominate the site if subsequent fires do not occur (B). Seed availability and site conditions help determine the relative proportions of each species in the stand. Where serotinous lodgepole pine was present in the preburn stand or where open-coned seed trees are nearby, lodgepole pine may be quite dense. Fires of all severities can remove seedlings and saplings, and the stand reverts to an herbaceous or shrub community. A dense to open stand of poles develops in the absence of fire (C). Low to moderate fires thin the stand and open areas for further conifer regeneration (C1). Moderate to severe fires remove most or all of the trees.

As Douglas-fir and lodgepole pine increase in diameter, they develop greater fire resistance. Low fires have little effect on older stands (D,F). Moderate fires can cause extensive mortality of lodgepole pine even in larger size classes. Douglas-fir is considerably more fire resistant and can survive most moderate-severity fires. An open stand of Douglas-fir results from fire in a mixed species stand (E). As the overstory canopy closes, the more tolerant Douglas-fir is favored over lodgepole pine in the understory. Low fires may provide microsites where some lodgepole pine can become established, maintaining the species in the stand (F). In the absence of fire, the result is a climax stand in which lodgepole pine has been entirely replaced by Douglas-fir (G). The thick bark of old-growth trees protects them from low and moderate fires. Small openings created by fire are quickly repopulated with Douglas-fir seedlings. Only severe fires are a danger to the climax stand, and when they do occur, even the largest trees are destroyed. The stand then reverts to herbs and shrubs (A). When large fires occur lodgepole pine may persist for some time, particularly where it is serotinous, and Douglas-fir must reinvade from unburned edges.

Succession With Aspen—The initial postfire herb community (fig. 12B) will rapidly give way to a stand of aspen resprouts (B). Some Douglas-fir may establish in openings. Any fire in this stage will destroy the stand. In the absence of fire, a pole-sized stand of aspen develops, with slower growing Douglas-fir in the understory (C). Low fires open the stand, providing microsites where aspen suckers and Douglas-fir seedlings can become established. Moderate fire probably eliminates much of the Douglas-fir and most aspen, and aspen suckers again dominate the postfire site. If fire does not occur in this stage, a mixed stand develops (D). Douglas-fir shares the overstory with aspen, and Douglas-fir dominates the understory. Moderate fires remove the understory and kill aspen stems, creating an open Douglas-fir stand with resprouting aspen (D1). Low fires maintain the stand, opening gaps for regeneration of either species. If no fires occur, aspen begins to break up (E). Once Douglas-fir makes up a significant part of the overstory, it continues to be favored by low to moderate fire. Older trees are fire-resistant, and the overstory remains intact. This environment is too shady to sustain aspen resprouts. Moderate fires result in a more open stand with Douglas-fir, and some residual aspen in canopy openings. The climax stand is a multiaged, Douglas-fir forest (F). If there is a severe fire after the remaining aspen roots have died, the successional sequence resembles that where Douglas-fir is the only seral and climax species.

Fire Management Considerations

Fire can reduce fuel hazards, recycle nutrients, and provide mineral seedbed. Where aspen is a seral species, fire can stimulate suckering and rejuvenate stands. In wildlife habitat, fire top-kills decadent shrubs, which often respond by resprouting prolifically. Resprouts are more succulent and nutritious than the old, woody stems.

Fire may be used to control pathogens. It can reduce the susceptibility of Douglas-fir stands to western spruce budworm by thinning stands (see Fire Group Two). Fire can sanitize postlogging stands by removing residual trees infested with dwarf mistletoe (*Arceuthobium douglasii*)(Alexander and Hawksworth 1975).

Burning prescriptions should be written so as to leave some overstory trees on treated sites. Douglas-fir regenerates most successfully in small openings. Small openings may reduce competition from pinegrass, although scarification is often necessary for seedling establishment. Occasional spring fires and moderate amounts of shade enhance the production of huckleberries on the *Pseudotsuga menziesii/Vaccinium globulare* type.

FIRE GROUP FOUR: ASPEN-DOMINATED COMMUNITY TYPES

Stable Aspen Community Types

Populus tremuloides/Amelanchier alnifolia-Symphoricarpos oreophilus/Calamagrostis rubescens c.t. (POTR/AMAL-SYOR/CARU), aspen/serviceberry-mountain snowberry/pinegrass

Populus tremuloides/Amelanchier alnifolia-Symphoricarpos oreophilus/Tall Forb c.t. (POTR/AMAL-SYOR/TALL FORB), aspen/serviceberry-mountain snowberry/pinegrass/tall forb

Populus tremuloides/Amelanchier alnifolia/Tall Forb c.t. (POTR/AMAL/TALL FORB), aspen/serviceberry/tall forb

Populus tremuloides/Amelanchier alnifolia/ Thalictrum fendleri h.t. (POTR/AMAL/THFE), aspen/serviceberry/Fendler's meadowrue

Populus tremuloides/Artemisia tridentata c.t. (POTR/ARTR), aspen/big sagebrush

Populus tremuloides/Carex rossii c.t. (POTR/CARO), aspen/Ross sedge

Populus tremuloides/Equisetum arvense c.t. (POTR/EQAR), aspen/common horsetail

Populus tremuloides/Shepherdia canadensis c.t. (POTR/SHCA), aspen/russet buffaloberry

Populus tremuloides/Symphoricarpos oreophilus/ Calamagrostis rubescens c.t. (POTR/SYOR/CARU), aspen/mountain snowberry/pinegrass

Populus tremuloides/Symphoricarpos oreophilus/ Thalictrum fendleri c.t. (POTR/SYOR/THFE), aspen/mountain snowberry/Fendler's meadowrue

Populus tremuloides/Symphoricarpos oreophilus/ Tall Forb c.t. (POTR/SYOR/TALL FORB), aspen/mountain snowberry/tall forb

Populus tremuloides/Tall Forb c.t. (POTR/TALL FORB), aspen/tall forb

Populus tremuloides/Thalictrum fendleri c.t. (POTR/THFE), aspen/Fendler's meadowrue

Populus tremuloides/Wyethia amplexicaulis c.t. (POTR/WYAM), aspen/northern mule's ears

Aspen Community Types Probably Seral to Conifers

Populus tremuloides-Abies lasiocarpa/Amelanchier alnifolia c.t. (POTR-ABLA/AMAL), aspen-subalpine fir/serviceberry

Populus tremuloides-Abies lasiocarpa/Pedicularis racemosa c.t. (POTR-ABLA/PERA), aspen-subalpine fir/pedicularis

Populus tremuloides-Abies lasiocarpa/Shepherdia canadensis c.t. (POTR-ABLA/SHCA), aspen-subalpine fir/russet buffaloberry

Populus tremuloides-Abies lasiocarpa/Tall Forb c.t. (POTR-ABLA/TALL FORB), aspen-subalpine fir/tall forb

Populus tremuloides-Abies lasiocarpa/ Symphoricarpos oreophilus c.t. (POTR-ABLA/SYOR), aspen-subalpine fir/mountain snowberry

Populus tremuloides-Abies lasiocarpa/ Symphoricarpos oreophilus/Thalictrum fendleri c.t. (POTR-ABLA/SYOR/ THFE), aspen-subalpine fir/mountain snowberry/Fendler's meadowrue

Populus tremuloides-Pinus contorta/Carex geyeri c.t. (POTR-PICO/CAGE), aspen-lodgepole pine/elk sedge

Populus tremuloides-Pinus contorta/Symphoricarpos oreophilus c.t. (POTR-PICO/SYOR), aspen-lodgepole pine/mountain snowberry

Populus tremuloides-Pseudtosuga menziesii/ Amelanchier alnifolia c.t. (POTR-PSME/AMAL), aspen-Douglas-fir/serviceberry

Populus tremuloides-Pseudotsuga menziesii/ Calamagrostis rubescens c.t. (POTR-PSME/CARU), aspen-Douglas-fir/pinegrass

Populus tremuloides-Pseudotsuga menziesii/ Symphoricarpos oreophilus c.t. (POTR-PSME/SYOR), aspen-Douglas-fir/mountain snowberry

Aspen Community Types That Are Grazing Disclimaxes

Populus tremuloides/Astragalus miser c.t. (POTR/ASMI), aspen/woody milkvetch

Populus tremuloides/Poa pratensis c.t. (POTR/POPR), aspen/Kentucky bluegrass

Populus tremuloides/Bromus carinatus c.t. (POTR/BRCA), aspen/California brome

Vegetation

Fire Group Four is made up of community types where aspen appears to be the climax or long-term seral dominant. The basic ecology and fire management discussed here are applicable to the seral communities in other fire groups where aspen is the primary focus of management activities.

Aspen is a widespread species throughout the Rocky Mountain and Intermountain West. There are more than 2 million acres of aspen in the Intermountain Region of the Forest Service and an average of 125,000+ acres in each of the 16 National Forests in this region (Spillett n.d.). Aspen is able to tolerate a wide range of environmental conditions and, as a consequence, is associated with a diverse number of understory shrub and herbaceous species. Shrub species common to a number of community types include *Amelanchier alnifolia*, *Berberis repens*, *Prunus virginiana*, *Rosa* spp., and *Symphoricarpos oreophilus*. Aspen stands have a particularly rich forb component, with *Achillea millefolium*, *Agastache urticifolia*, *Aquilegia coerulea*, *Aster engelmannii*, *Corallorhiza maculata*, *Delphinium* spp., *Descurania richardsonii*, *Fragaria vesca*, *Geranium viscosissimum*, *Hedysarum boreale*, *Lathyrus lanzwertii*, *Ligusticum filicinum*, *Lupinus argenteus*, *Osmorhiza chilensis*, *Perideridia gairdneri*, *Potentilla gracilis*, *Smilacina stellata*, *Thalictrum fendleri*, and *Valeriana occidentalis* occurring in many community types. The number of graminoid species is considerably less, but *Calamagrostis rubescens*,

Carex rossii, *Elymus caninus*, *Elymus glaucus*, *Festuca thurberi*, *Poa nervosa*, *Poa pratensis*, and *Stipa occidentalis* may all be significant members of the community.

Forest Fuels

Brown and Simmerman (1986) classified aspen stands in southeastern Idaho and western Wyoming into five fuel types (see table 7). Average fuel loads and shrub cover in the five types are presented in table 8.

Some of the conclusions of their study were:

1. Shrubs contributed significantly to fine fuel loadings.
2. Fine fuel loadings differed substantially between the shrub and forb understory types and between the aspen/tall forb and aspen/low forb types.

Table 7—A vegetation classification of aspen fuels and flammability (Brown and Simmerman 1986)

Characteristics	Vegetation - fuel types: Aspen/ shrub	Aspen/ tall forb	Aspen/ low forb	Mixed/ shrub	Mixed/ forb
Overstory species occupying 50 percent or more of canopy	Aspen	Aspen	Aspen	Conifers	Conifers
Shrub coverage, percent	Greater than 30	Less than 30	Less than 30	Greater than 30	Less than 30
Community type understory indicator species that may be present	*Prunus* *Bromus* *Amelanchier* *Shepherdia* *Symphoricarpos* *Artemisia* *Juniperus* *Pachistima*	*Ranunculus* *Heracleum* *Ligusticum* *Spiraea* *Calamagrostis* *Rudbeckia* *Wyethia*	*Prunus* *Berberis* *Arnica* *Astragalus* *Thalictrum* *Geranium* *Poa*	*Ligusticum* *Shepherdia* *Spiraea* *Amelanchier* *Symphoricarpos*	*Pedicularis* *Berberis* *Arnica* *Calamagrostis* *Thalictrum*

Table 8—Average fuel loadings and shrub cover from sampled stands representing the aspen fuel types sampled in southeastern Idaho and western Wyoming (Brown and Simmerman 1986)

Fuel	Aspen/ shrub	Aspen/ tall forb	Aspen/ low forb	Mixed/ shrub	Mixed/ forb
	Lb/acre				
Herbaceous	670 (230-1,000)	1,330 (1,030-2,020)	300 (180-460)	90 (80-90)	290 (10-550)
Shrubs[1]	3,170 (980-6,150)	110 (0-440)	260 (0-630)	3,040 (2,480-3,610)	630 (100-1,350)
Litter	1,810 (420-2,810)	1,600 (790-2,240)	1,350 (170-2,740)	1,980 (1,920-2,040)	1,680 (740-2,560)
Fines[2]	6,140 (4,030-9,390)	3,170 (1,970-3,990)	2,430 (1,640-3,330)	6,050 (5,850-6,250)	3,070 (2,150-3,560)
Downed woody 0-1-inch	2,440 (710-4,220)	1,080 (620-1,440)	2,600 (1,460-3,690)	4,240 (3,400-5,080)	2,710 (1,440-3,900)
Downed woody 0-3-inch	7,020 (3,580-12,510)	7,340 (1,510-16,210)	5,720 (3,290-7,600)	6,970 (5,550-8,390)	7,810 (4,090-12,250)
	Percent				
Shrub cover	40 (30-60)	10 (0-20)	10 (0-30)	60 (60-70)	20 (10-30)

[1]Shrubs include foliage and stemwood.
[2]Fines include live and dead herbaceous plants and shrubs, litter, and 0-3-inch downed woody fuel.

3. Herbaceous vegetation in the aspen/tall forb class averaged two to four times greater than in the other classes.

4. Litter loadings differed greatly among individual stands within types, but the average difference among types was small and not meaningful.

5. Loadings of downed woody fuel 0 to 1 and 0 to 3 inches (0 to 2.54 cm and 0 to 7.62 cm) in diameter also varied substantially from stand to stand. The mixed types appear to have slightly more downed woody fuel than the other types because conifer crowns shed more small dead twigs and branches than aspen. Considering the variation among stands, however, the differences among types appear insignificant. This emphasizes the need to appraise downed woody fuels on an individual stand basis.

6. Differences in dead fuel loadings between the aspen/shrub and mixed/shrub types are small. Nevertheless, these types should be regarded separately because conifers in the mixed types are likely to torch, thus creating a more intense fire. The same relationship exists between the aspen/low forb and mixed/low forb types.

Heavy grazing can reduce fine fuels so that fireline intensity and rates of spread may be as low as one-tenth that of ungrazed stands. Fire in aspen stands will not sustain fire spread unless flame lengths are 1 to 1.5 ft (0.3 to 0.5 m), which requires at least 50 percent cured herbaceous vegetation in the aspen/shrub and aspen/tall forb types. Surface fuels in pure aspen stands are not typically conducive to prolonged flaming or burnout owing to a lack of intermediate fuels (0.4 to 3.2 inches [1 to 8 cm] in diameter). In all cases, the presence of conifers increases stand flammability significantly (Brown and Simmerman 1986).

Role of Fire

Aspen stands in the West may be even-aged or uneven-aged. Uneven-aged stands are more characteristic of situations where aspen is the climax dominant. Here, regeneration takes place as a gradual process, with new suckers establishing as older stems die from age or disease. Uneven-age structure also occurs where aspen clones are invading surrounding grass or shrubland. The role of fire in these stands is not clear. Where aspen forms even-aged stands, it is generally seral to one or more conifer species and results from rapid suckering after disturbance. Fire plays a significant role in maintaining and regenerating aspen on these sites (fig. 13).

Figure 13—Fire maintains aspen cover by removing conifers and stimulating aspen resprouting. When fire is excluded on seral aspen sites, conifers may invade and eventually dominate stands. Aspen fails to reproduce and is ultimately lost as succession proceeds (Caribou National Forest).

According to DeByle and others (1987), fire frequencies of 100 to 300 years appear to be appropriate for maintaining most seral aspen stands. In a more localized study, the fire history of two aspen-conifer stands was studied in the Fontenelle Creek drainage of Wyoming. The mean fire-free interval was estimated to be 40 years. Fires in this area burned in a mosaic pattern of severities, from stand-replacement to low fires that scarred but did not kill the relatively thin-barked lodgepole pine on the site (Arno 1981). Where aspen does not occur with conifers the fire-free interval may be considerably longer.

Fires in aspen and aspen-conifer stands before and during the mid-19th century were apparently larger and more frequent than has been true since. DeByle and others (1987) list several factors possibly contributing to the reduction in fire occurrence in modern times:

1. Direct control of wildfires during the past 50 years has been especially effective, particularly in the aspen type.
2. For the past century, most aspen in the West has been grazed by domestic livestock. Thus, each summer fine fuels have been reduced and do not contribute to fire spread.
3. During the 19th century, Native Americans were removed from most of their former homeland. Their deliberate use of fire on wildlands prior to Caucasian settlement is well documented.
4. Perhaps most of the flammable aspen-conifer mixed stands were burned during the late 1800's.

In this last scenario, aspen stands would have been relatively nonflammable in the intervening decades between the middle to late 1800's. Mixed conifer-aspen stands may now be approaching conditions conducive to large stand-replacing fires.

Regardless of the cause, the lack of fire or other mechanisms of regeneration has permitted the decline of many thousands of acres of aspen throughout the West.

Despite its frequent dependence on fire for successful regeneration, aspen is extremely fire-sensitive. Even low-severity fires will kill aspen because of its thin bark. Trees not killed outright by the heat of the fire often die by the second or third growing season, succumbing to disease or stressful climatic conditions. The relationship between fire severity, mortality, and suckering is discussed by Brown and DeByle (1987). Suckering is a highly variable process. Because of the relationship between auxin production by above-ground stems and the release of root suckers, killing most or all of the clonal stems may help to stimulate good resprouting. But the ability to sucker is governed by clonal genetics, stand vigor, and postfire site factors as well as hormonal balance. Thus, it is difficult to predict the amount of suckering in a particular stand after a specific fire treatment. Moderate-severity fire may be more likely to produce good suckering when compared with low fires, which may not kill enough stems, or high-severity fires, which may kill shallow aspen roots (Brown 1990).

Forest Succession

The successional pathway described here (fig. 14) is applicable for sites with climax or persistent aspen stands. Long-term effects of fire exclusion on these stands is not understood. The biological response of climax aspen to fire is the same as seral aspen.

A short-lived herb stage follows a stand-replacement fire. Resprouting generally begins within the first growing season following fire, although suckering after a severe burn may be delayed because the resprouts must come from a greater depth (B). Any fire at this stage will recycle the stand. Repeated fires may maintain aspen as a shrub. Low fire in an immature or mature stand (C and D) would open the stand and may stimulate some suckering. This results in a two-storied aspen stand (E1). Succeeding fires may be more likely to be moderate to severe because of the downed stems left by low fire. Moderate to severe fires return the stand to the herb state. Climax all-aged aspen is the result of a prolonged period without fire (F). Mature stems continue to degenerate and are replaced by suckers arising in the openings. Although low fires may not kill aspen stems outright, injured stems are very susceptible to invasion by fungal pathogens. If the vigor of the clone is reduced by disease, there may be less suckering. This may slow succession to the climax state or, in extreme cases, may give a competitive advantage to shrubs and herbaceous vegetation, which may then dominate the site.

Heavy browsing on aspen suckers stimulated by overstory removal may lower clone vigor to the point that suckering no longer takes place. A shrub or herb disclimax results (F1). Browsing pressure may also permit aspen regeneration but prohibit the development of trees. Aspen will grow instead in a dense shrub form.

Fire Management Considerations

Aspen is a highly valued species for many reasons. Aspen stands provide excellent forage for livestock and wildlife, with production values of up to 3,000 lb/acre recorded for some stands (Mueggler 1988). Aspen provides quality browse and cover for many wildlife species. Rapid development of urban and agricultural areas in the Mountain States is increasing the utilization of aspen stands as a source of fuel, fiber, and water. Aspen stands have a water-yielding capacity

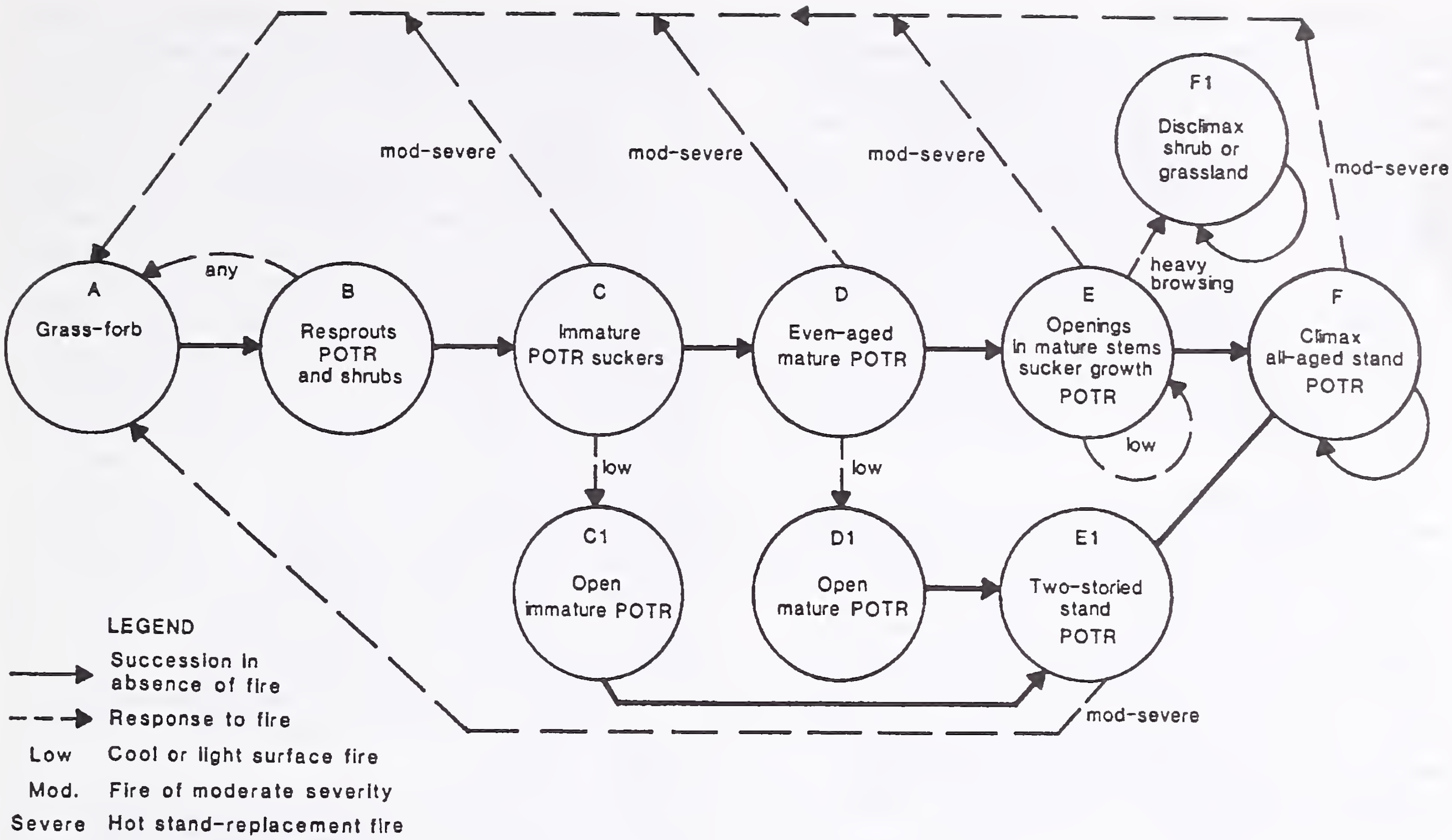

Figure 14—Hypothetical fire-related successional pathways for Fire Group Four habitat types.

superior to conifer-dominated stands (DeByle 1985; Jaynes 1978), a potentially critical resource in coming decades. An increase in population in the region has also increased the need for recreation opportunities, and aspen forests are popular for picnicking, hiking, or viewing. In the Intermountain area as a whole, two-thirds of aspen stands are at least 96 years old and 90 percent are at least 75 years old. Western aspen usually matures between 60 and 80 years of age and deteriorates rapidly after 120 years. Approximately 94 percent of aspen stands appear to be mature or overmature (Mueggler 1989). Whether or not some kind of treatment is needed to assure the continued presence of aspen in these stands depends on the degree of conifer invasion and the relative success of regeneration. Mueggler (1989) has developed a decision tree as an aid in determining the need for treatment (fig. 15).

Regeneration of seral aspen stands requires killing most of the aboveground stems in a clone. This may be achieved by clearcutting, top-killing with herbicides, or using prescribed fire. Where clearcutting is not feasible, fire is the most acceptable management tool (DeByle and others 1987).

Before planning any manipulation of aspen, the manager will want to consider carefully what successional stage, or pattern of successional stages,

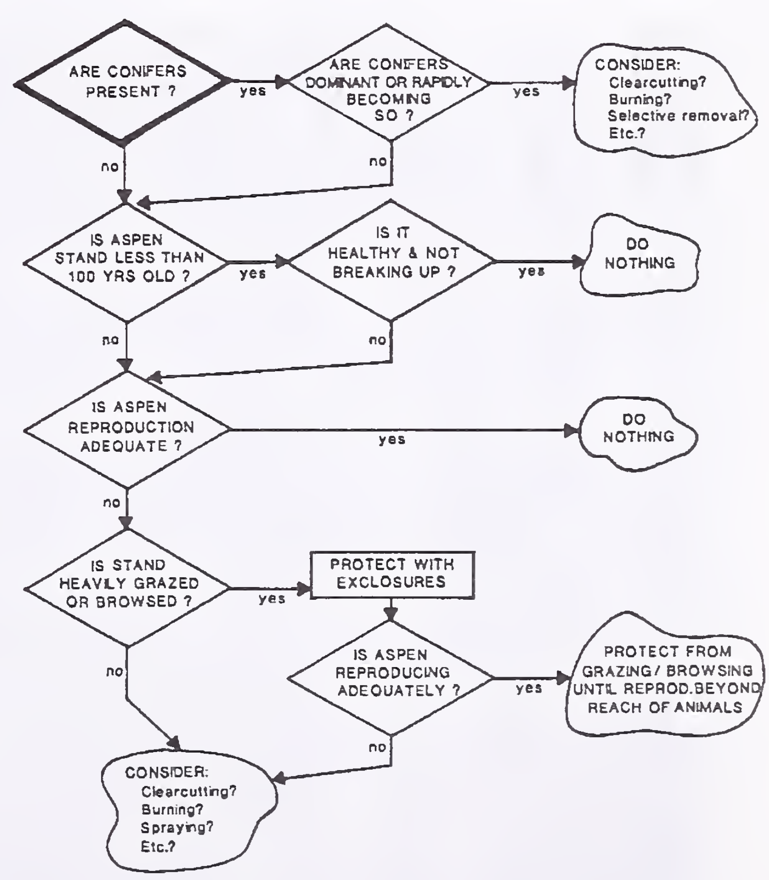

Figure 15—General decision-making tree for maintaining aspen stands in the Intermountain Region (Mueggler 1989).

best satisfies management objectives. Cattle prefer grazing in relatively open stands, free of dense reproduction. Elk may use young, sapling aspen as a source of winter browse. Early successional aspen stands provide structurally optimum habitat for ruffed grouse (Stauffer and Peterson 1985). Where hunting pressure is intense, later successional stands with a higher density of young conifers may be desirable to provide adequate hiding cover and prevent overharvesting of big game. Water yield is greatest in the earliest stages of succession. A mosaic of different developmental stages over the landscape maximizes the value of these stands for a variety of uses.

Fire can be used to enhance many of the values associated with aspen. But not all stands are equally suited to fire use. Aspen forests are considered difficult to burn when compared to most conifer stands. Undergrowth is abundant, and fine fuel moistures remain high for most of the growing season (fig. 16). Brown and Simmerman (1986) have provided guidelines for determining the potential flammability of aspen stands included in burning prescriptions. Much of the information in this section is taken from their publication.

Aids to flammability in aspen stands include the presence of large downed woody fuel, small conifers, and open canopy. Autumn leaf fall does not aid flammability to any great extent, but leaf litter may help sustain a fire in marginal conditions. Relative probabilities of successful fire application under different fuel conditions are presented in table 9.

Determining when fuels are ready to burn is more complicated in aspen forests than in most other vegetation types. Finding the proper time for ignition requires waiting until live fuels are adequately cured, and windspeed and dead fuel moistures are conductive to fire spread. Adequate curing is particularly important where herbaceous vegetation is the primary fine fuel. Curing increases the flammability considerably in these types. Aspen stands should be burned as soon as possible after vegetation is adequately cured. Delays in burning will result in fewer accomplishments because the onset of autumn weather frequently brings rain or snow. Figure 17 illustrates the fluctuation of live fuel moisture with season and precipitation for fine fuels collected in a western Wyoming aspen stand.

The method of fire ignition affects potential success of aspen burns:

> Method of ignition should be carefully considered in planning prescribed fire in aspen because it affects the conditions chosen for burning and chances of success. Both hand-held and aerial ignition

Figure 16—The lush undergrowth typical of many aspen stands limits fire spread because of high fine fuel moistures (Bridger-Teton National Forest).

Table 9—Probabilities of successfully applying prescribed fire in aspen forests according to fuel types and the influence of grazing and quantities of downed woody material (Brown and Simmerman 1986)

		Fuel types				
Grazing	**Woody fuel**	**Aspen/ shrub**	**Aspen/ tall forb**	**Aspen/ low forb**	**Mixed/ shrub**	**Mixed/ forb**
Ungrazed	Light	high	moderate	low	high	moderate
Ungrazed	Heavy	high	moderate	low	high	high
Grazed	Light	moderate	low	low	moderate	low
Grazed	Heavy	high	low	low	high	moderate

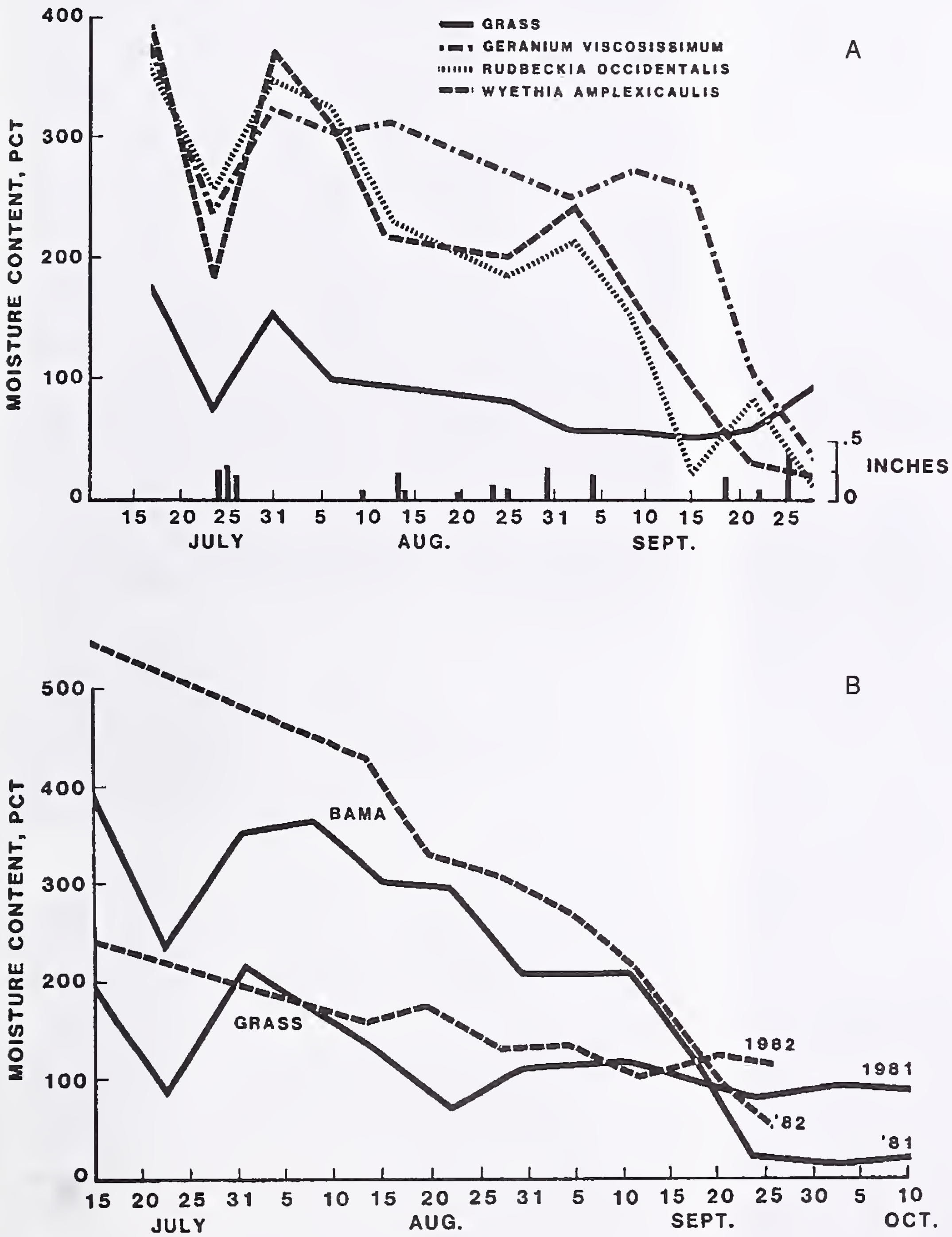

Figure 17—Live fuel moisture contents of fine fuels collected at different dates and different precipitation levels from an aspen stand on the Kemmerer Ranger District, Bridger-Teton National Forest, WY. (A) Moisture content of grasses (*Elymus* and *Bromus* spp.) and forbs. The bars along the horizontal axis show 1981 precipitation. (B) Moisture content of *Balsamorhiza macrophylla* and grass (*Elymus* and *Bromus* spp.). Precipitation during August and September was 1.56 inches in 1981 and 4.66 inches in 1982 (Brown and Simmerman 1986).

methods can be used successfully; however, aerial ignition with jelled gasoline permits burning at higher fine fuel moisture contents than possible using hand ignition because more heat can be generated for preheating adjacent fuels, particularly where fuels are abundant and continuous. Aerial ignition can create larger flames to kill unwanted vegetation and get the fire to spread in marginal fuels, particularly where fuels are abundant and continuous. (Brown and Simmerman 1986)

If simply retaining the aspen type is desired, any fire severity will probably suffice. To obtain the greatest sucker densities, moderate burns are advised. High-severity fires may be useful in limited conditions, for example, where ceanothus stimulation is desirable or in higher elevation spruce fir types where only a high-severity fire is sustainable because of the scant fuel loading. Where commercial development of aspen is the objective, clearcutting may produce more consistent stand regeneration than fire. On sites where Douglas-fir or ponderosa pine are undesirable competing conifers, low fires may actually enhance their reproduction over aspen if the conifers survive. They will quickly establish in the newly exposed mineral soil (Brown and Simmerman 1986).

Postfire conditions will impact stand reestablishment. Heavy sucker utilization by wildlife may be one limitation. In Wyoming, on Breakneck Ridge in the Gros Ventre drainage, postburn sucker numbers doubled the second year after fire. By the third year, though, there were 15,000 to 20,000 suckers per hectare, similar to the numbers that existed before the fire. Because of heavy winter elk use, these densities are probably not enough to regenerate the stand (Bartos and Mueggler 1981). Treatment areas that are too small, that are isolated, or that are being browsed by ungulates may suffer overuse (Bartos and Mueggler 1979; Gruell and Loope 1974). Where wild ungulate use is not heavily concentrated, browsing in burned areas is less of a problem (Spillett n.d.). Domestic animal use, especially that of sheep, can also impact regeneration success (Smith and others 1972).

FIRE GROUP FIVE: PERSISTENT LODGEPOLE PINE COMMUNITY TYPES

Community Types, Phases

Pinus contorta/Arnica cordifolia c.t. (PICO/ARCO), lodgepole pine/heartleaf arnica
Pinus contorta/Carex geyeri c.t. (PICO/CAGE), lodgepole pine/elk sedge
Pinus contorta/Carex rossii c.t. (PICO/CARO), lodgepole pine/Ross sedge
Pinus contorta/Calamagrostis rubescens c.t. (PICO/CARU), lodgepole pine/pinegrass
Pinus contorta/Juniperus communis c.t. (PICO/JUCO), lodgepole pine/common juniper
Pinus contorta/Linnaea borealis c.t. (PICO/LIBO), lodgepole pine/twinflower
Pinus contorta/Shepherdia canadensis c.t. (PICO/SHCA), lodgepole pine/russet buffaloberry
Pinus contorta/Spiraea betulifolia c.t. (PICO/SPBE), lodgepole pine/white spirea
Pinus contorta/Vaccinium globulare c.t. (PICO/VAGL), lodgepole pine/blue huckleberry
Pinus contorta/Vaccinium scoparium c.t. (PICO/VASC), lodgepole pine/grouse whortleberry

Vegetation

Fire Group Five consists of communities dominated by lodgepole pine that frequently persists for long periods of time and in some cases appears to be climax. These communities may be the seral stages of habitat types in the Douglas-fir, subalpine fir, Engelmann spruce, and whitebark pine habitat type series. They may be found in areas of cold air drainage, or where soils and topography favor lodgepole pine over other species. Large acreages of persistent lodgepole develop in acidic soils made up of coarse, alluvial material derived from rhyolite, sandstone, or granitic rock on sites with gently sloping to nearly level topography. Drought or nutrient stress may inhibit competition from other conifers on these sites (fig. 18).

Lodgepole pine is a seral species in several fire groups discussed in this document. The role of fire described here is also applicable to lodgepole pine where it appears to be less persistent.

The understory of persistent lodgepole pine stands is not usually diverse or dense. Harsh growing conditions and/or a dense overstory canopy permit relatively few species to flourish. Common shrubs may include *Berberis repens*, *Juniperus communis*, *Linnaea borealis*, *Lonicera utahensis*, *Rosa* spp., *Shepherdia canadensis*, *Vaccinium globulare*, and *Vaccinium scoparium*. On some sites *Amelanchier alnifolia*, *Pachistima myrsinites*, *Prunus virginiana*, or *Symphoricarpos oreophilus* may be important. Graminoids are usually sparse. *Carex geyeri* and *Carex rossii* have the most significant coverage. *Poa nervosa* is also present in lesser quantities. Forbs may include *Antennaria racemosa*, *Arnica cordifolia*, *Astragalus miser*, *Lupinus* spp., *Pyrola chlorantha*, and *Pyrola secunda*.

Forest Fuels

Stand development, vegetation mortality, and fuel accumulation interact dynamically with fire in the lodgepole pine forest (Brown 1975). The type and

Figure 18—A mature lodgepole pine stand on the Yellowstone Plateau. The harsh environment in this region leads to slow growth, a longer fire-free interval, and the attainment of greater age than is usually true for lodgepole pine in other areas.

degree of vegetation mortality affects the fuel buildup, which in turn determines the severity of later fires and subsequent stand regeneration. Historically, fire probably generated most of the surface fuel in lodgepole pine stands. Competition between densely stocked trees can result in further fuel buildup from suppression mortality (fig. 19).

Measurements of downed woody fuel loadings have been reported for Montana lodgepole pine stands. Average fuel loads are 15 to 18 tons/acre (34 to 40 metric tons/hectare) although maximum loads were found to be much higher. Typically, most of this loading was in the large fuel (greater than 3 inches [7.62 cm]) category. The nature of fuels changes over time in lodgepole pine stands, although the amount of fuel produced over time appears to be quite variable (Brown and See 1981). A classification that relates lodgepole pine stand age and flammability has been developed for Yellowstone National Park (Despain n.d.; Romme and Despain 1989):

LP-0 (Young Stands)

The earliest stage of post-fire succession is LP-0. Initially the vegetation is dominated by herbs and small shrubs, most of which resprouted from root stocks that survived the fire. Within a few years, these plants may become larger and more productive than they were before the fire because they are no longer competing with trees for light, water, and nutrients. Fire-killed trees, both standing and fallen, are conspicuous in this stage. Over the first 10 to 20 years after the fire, lodgepole pine seedlings establish themselves and slowly grow to overtop the herbs and shrubs.... The LP-0 stage lasts until this pioneer generation of lodgepole pine growth is large

Figure 19—Dense lodgepole pine stands can accumulate large amounts of downed woody material as a result of suppression mortality or pine beetle epidemic.

enough to form a closed canopy and begins to shade the forest floor, a span of about 40 years on most sites (Romme and Despain 1989).

Fuels in this type consist mainly of forbs, grasses, and rotten logs. Sound logs begin to rot and seeds germinate immediately after a fire. As time goes on, the number of rotten logs, tree seedlings, and saplings increases. Under normal moisture conditions only the rotten logs burn, predrying and burning some of the herbaceous growth next to them. Occasional small trees or clumps of small trees burn if fuel conditions at their base are just right. If the firebrand rain is heavy enough, most of the rotten logs will burn. Under very dry conditions (drought), right wind, and moisture conditions, fire spread through this type is possible, though rare. Fire starts are moderately common in this type because of the rotten wood (Despain n.d.).

LP-1 (Immature Stands)

The next successional stage is called LP-1 and is characterized by a dense stand of small lodgepole. Competition for nutrients, water, and light may be intense among these young trees and many of the weaker trees die, producing a natural thinning of the stand. The herbs and shrubs on the forest floor become more sparse than they were in the previous stage, apparently because they are suppressed by the maturing trees. Almost all of the fire-killed trees have fallen and are now large decomposing logs on the forest floor. This stage usually lasts until the trees reach their full size and the natural thinning process is completed, generally from 40 to 150 years (Romme and Despain 1989).

Fuels here are nearly all in the crowns of the doghair lodgepole. The compact needle litter is difficult to burn. Under normal fire season moisture this type is nearly unburnable. Fire brands may find an occasional rotten log and burn out a small spot. Under very dry conditions with high winds, fire will spread through the canopy if a crowning fire reaches the stand. Fire spread, however, will stop when the wind ceases. There are no fuels to get the fire back into the canopy even if the wind should return. Fire starts in this type are very rare to nonexistent (Despain n.d.).

LP-2 (Mature Stands)

Stands in the next stage, LP-2, still have a closed canopy, but they are usually less dense than the previous stage. Most of the dead trees, both those killed by the previous fire and those that died in the thinning process, have decomposed. The forest floor is now open and easy to walk through. The herbs and low shrubs become more abundant and tree saplings more prominent toward the end of this stage. These saplings may have been present for many years but were suppressed by the larger trees, or they may represent a second generation of trees that is just now becoming established. The species may be subalpine fir and Engelmann spruce on moist fertile sites, lodgepole pine on dry infertile sites, or Douglas-fir at lower elevations. This stage usually lasts from 150 to 300 years after the fire (Romme and Despain 1989).

Fuels in this type are largely herbaceous plants or low shrubs like grouse whortleberry (*Vaccinium scoparium*). Under normal conditions this type is very difficult to burn. The understory vegetation stays moist enough to retard fire spread. Very few rotten logs are available. Under very dry conditions the herbaceous growth may carry the fire. Fire spread, however, is very slow because the canopy keeps wind from reaching the flames. If a good understory of globe huckleberry (*V. globulare*) develops and trees killed by bark beetles begin to fall and contribute to understory fuels, crowning is possible. In the older stands sufficient young trees may be on hand to allow crowning. Bark beetle kill is common in this type; however, experience had shown that it affects fire behavior very little. The red crowns are much drier than the green crowns but crowning is still dependent on the ladder fuels or understory fuels. Fire starts are rare in this type (Despain n.d.).

LP-3 (Overmature Stands)

LP-3...is an old-growth forest...containing trees of many sizes and ages, as well as a variety of low shrubs and herbaceous plants. The LP-3 stage generally is reached after about 300 years of post-fire succession, and it slowly develops into the climax forest as the pioneer lodgepole die. The climax consists entirely of second-generation trees, and it persists until the next hot fire, which then initiates a new successional cycle. True climax is uncommon in Yellowstone, suggesting that fire usually recurs before the successional process is complete (Romme and Despain 1989).

Fuels in this type are right for burning. Young trees contribute to understory fuels and fuels continuous with the overstory. Spruce and fir trees are scattered among the overstory and may contribute to the dead and down fuels in the understory. On the better growing sites, globe huckleberry may also contribute significantly to the fuels. Lichen accumulations in older trees contribute to the fuel load and flashability [flammability] of the trees. Lightning strikes and other fire brands find an easily burnable substrate in these crowns. The bulk of the extreme fire behavior takes place in this type. Under normal moisture conditions this type burns. If winds are present, crowning and spotting are nearly inevitable. Without winds, torching occurs. Under dry conditions local crowning and smoke column development is possible even without wind. Spotting is very common and is the largest contributor to fire spread. Under wet conditions, these stands allow fires to smolder and persist, although spread is minimal. Deep litter and duff accumulations and rotten logs protected from precipitation by overstory trees provide sites where fires can persist even for several weeks. Most fires start in this type (Despain n.d.).

...the post-fire succession brings with it an important change in the flammability of the forests...the early stages (LP-0, LP-1 and at least the initial

period of LP-2) do not carry a crown fire as readily as the older stages, except during strong winds.... In late LP-2 and especially in the LP-3 and climax stages, flammability increases substantially, both because of the dead trees and other dead woody fuels that begin to accumulate on the forest floor and because of the small trees that are growing into the forest canopy. These small trees are flammable themselves, especially fir and spruce, and they also create continuity between the dead fuels on the ground and the live tree crown.

An analysis of 235 lightning-caused fires allowed to burn between 1976 and 1987 revealed that most fire starts occurred in LP-3 and climax forest stands ...(in 1988) strong winds drove (fires) through extensive areas of young forest in the extremely dry conditions of late August and early September...there are significant differences in flammability among the various stages of forest succession except in unusual (and infrequent) dry windy years (Romme and Despain 1989).

Brown (1975) characterized fuel cycles and fire hazard in lodgepole pine stands, as shown in figure 20. Curve A of that figure corresponds to what Muraro (1971) describes as typical fire hazard in lodgepole pine where young, especially dense stands are most hazardous. Least hazardous are moderately dense-to-open advanced, immature, and mature stands. Hazard increases as stands become overmature and as ground fuels build up from downfall and establishment of shade-tolerant species. Curve C depicts conditions not uncommonly found. Ground fuel quantities and fire potential remain relatively low throughout the life of the stand until it undergoes decadence. Individual stands can vary anywhere between curves A and C during younger growth periods, and develop higher fire potential at later periods of growth (curve B).

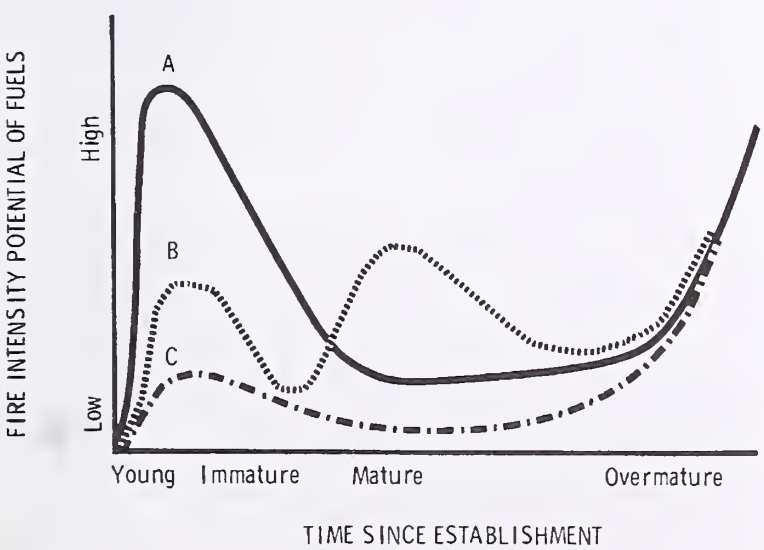

Figure 20—Fuel cycles and fire intensity potential in lodgepole pine. The three characteristic fuel cycles (A, B, and C) are described in the text (Brown 1975).

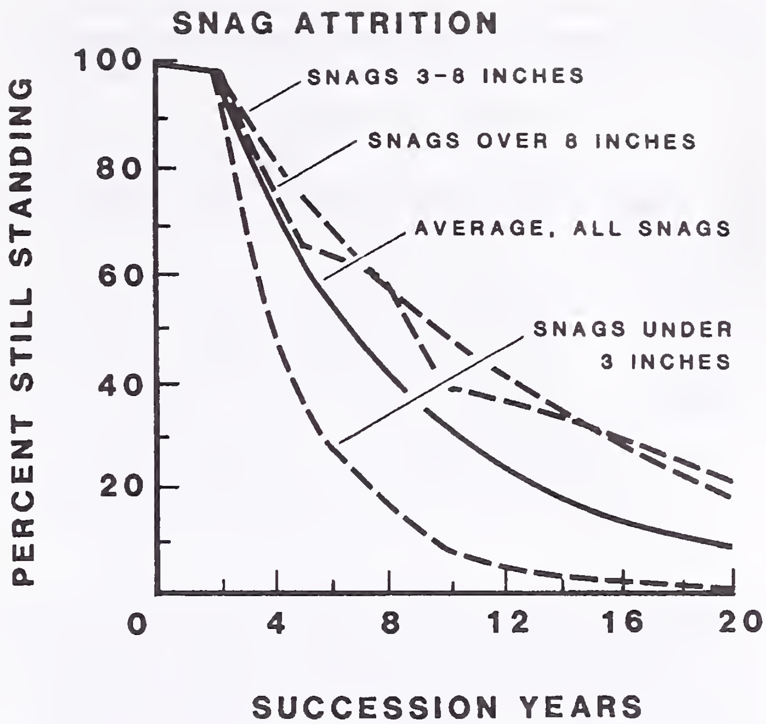

Figure 21—Percentage of lodgepole pine snags still standing, by year and diameter class, 1962-82, Sleeping Child Burn, Bitterroot National Forest, MT (Lyon 1984).

In a young lodgepole stand the snags created by the previous fire provide an immediate source of downfall. Lyon (1977, 1984) found that after 2 years with little windthrow, lodgepole pine snags on the Sleeping Child Burn (Bitterroot National Forest) fell at an annual rate of 13.4 percent (fig. 21). Overall, an average of 497 snags per acre was reduced to an average of 75 snags per acre after 15 years (table 10). After 21 years, nearly 93 percent of all snags had fallen.

Role of Fire

Fire perpetuates or renews stands of lodgepole pine. Where it is a seral species, without fire or other disturbance shade-tolerant trees will replace lodgepole because of its intolerance and mineral seedbed requirement. Bare mineral soil, whether caused by logging or fire, provides the best seedbed for lodgepole pine (Lotan 1975).

Lodgepole pine may have serotinous (closed) or open cones. The degree of serotiny can affect the age distribution in a stand. Seed from open-coned trees produces uneven-aged stands, where seedlings establish over a period of years. Closed-cone trees generally produce even-aged stands. They develop from the flush of seedlings that arises following the

Table 10—Average number of snags per acre by size class and year count, Sleeping Child Burn, Bitterroot National Forest, MT (Lyon 1977)(totals may not agree because of rounding)

Size class	Year 1962	1963	1966	1969	1971	1976
Inches						
Under 3	266	265	96	41	28	4
3 to 8	159	156	124	103	85	50
8 to 12	64	62	40	36	24	19
Over 12	7	7	7	6	4	3
Total	497	390	268	186	141	75

fire-induced release of large numbers of seeds on the freshly prepared mineral seedbed. Rocky Mountain lodgepole pine stands vary in their degree of serotiny. Proportions of serotinous trees range from 0 to 80 percent (Lotan 1975). Double burns or successive burns within a 50-year span favor serotiny. A mix of serotinous and nonserotinous trees usually results after low or moderate fires. A higher proportion of regeneration from serotinous trees follows severe crown fires. Over time, without fire, even stands with a very high proportion of closed cones can become predominantly open-coned as regeneration replaces the original trees (Brown 1988; Muir 1984). In mixed species stands, fire interrupts the course of succession, and increases the proportion of lodgepole with each burn.

Fires in lodgepole pine-dominated stands tend toward one of two extremes. They may smolder and creep slowly on the soil surface, consuming litter and duff, or act as high-intensity, stand-replacing crown fires. Most are low-intensity fires due to the generally sparse undergrowth and stand growth habit. Cool, moist conditions prevail under a dense, closed canopy, and fires that start here usually remain on the ground, smoldering for days or even weeks before extinguishing. Such fires have been observed in Yellowstone National Park (Brown and others 1975; Despain and Sellers 1977). High-intensity fires are most likely to occur where dead fuels have accumulated. Where there are concentrations of dead fuels or mixed dead and live fuels, individual trees or groups of trees may torch, and fire can continue to travel through the crowns aided by steep slopes and high winds. Though much less common, high-intensity crown fires account for most of the timber consumed. Summer wildfires may exhibit both types of fire behavior, depending on the diurnal weather fluctuations. The chance of crown fire occurring in lodgepole stands is governed by the amount of heat released from surface fuel, the height of tree crowns above the ground, and fire weather conditions. Stand conditions determine the fire potential, and this, in turn, is the result of stand disturbance history (Brown 1975). The kind of fire that occurs will determine stand density and the rate of succession. If open stands result, there will be a faster rate of succession (Brown 1975).

Lotan and others (1985) have summarized the effects of high- and low-intensity fires on stand establishment:

High-Intensity Fires

1. Creates good seedbed conditions on mesic and wet sites, and when seed is abundant, dense stands are established. On dry sites, however, low stocking can result because of poor moisture conditions.
2. Crown fires usually cause maximum release of stored seed. In surface fires with considerable crowning, mineral soil is exposed, serotinous cones open, and if seed is abundant, a dense stand results. Occasionally, severe crown fires consume up to ½-inch (1.3 cm) diameter fuel, destroying much of the seed supply, and a lower density stand results.
3. When seedbed conditions, seed supply, soil moisture, and other factors are favorable for stand establishment, extremely high stocking (leading to stagnated stands) frequently results.
4. Competition from understory vegetation, particularly grass, can decrease stand density even if other factors influencing establishment are favorable.

Low-Intensity Fires

1. Moisture content of duff is an important factor in determining level of stocking. When duff is dry a low-intensity fire will expose mineral soil, resulting in a high level of stocking. When duff is moist, fire will expose less mineral soil, resulting in poor seedbed conditions and low stocking.
2. Mortality may be minimal or sporadic. Sometimes widely spaced stands result. In time, two-aged or three-aged stands can develop.
3. In stands of mixed species, the survival of lodgepole pine depends on its fire resistance relative to other species as well as the seed potential of all species. Post-fire species composition, age structure, and density of mixed stands vary considerably depending on fire characteristics and many other interrelated factors.

Romme (1982) believed that fewer low-intensity fires have occurred in the Yellowstone region than in the Northern Rocky Mountains. This may set the stage for less frequent but more destructive fires because of fuel accumulation. Because of low site potential, however, accumulating hazardous amounts of fuel may take 350 years. He concluded: "Fire controls landscape dynamics of Yellowstone not because it recurs very frequently, but because very large areas are affected when it does occur and vegetational development is relatively slow." Chapman (1990) believes that fires may occur as frequently in

western Wyoming as they do in the Northern Rockies, but that they may be less detectable because the majority are short-lived and consume relatively little fuel. Reported fire frequencies for lodgepole pine stands vary from 22 years in the Bitterroot Valley of western Montana (Arno 1976) to 300 plus years in Yellowstone National Park (Romme 1982). The interval between any two fires in an area may only be a few years. Regional fire frequency varies with summer dryness and lightning occurrence. Locally it depends on slope, aspect, elevation, and natural fire barriers. Habitat type may affect potential for fire within Fire Group Five. In western Yellowstone, the *Pinus contorta/Carex geyeri* community type had a total fire frequency nearly two times that of the *Abies lasiocarpa/Vaccinium scoparium* habitat type, although frequency of major fires (>10 acres [>4 ha]) was approximately equal. The *Abies lasiocarpa/Vaccinium scoparium* stands were probably less prone to fire because of greater precipitation and protective topography (Romme 1982).

In most years, the even distribution of annual precipitation, year-round freezing temperatures, and generally low wind velocities tend to limit fire potential in the Bridger-Teton Wilderness. There is, however, evidence that "periodic, extensive fires" occurred in the past, as evidenced by fire scars and the large acreages presently dominated by lodgepole pine (Reese and others 1975). The size of fires as well as their frequency depends on weather conditions. Large fires may occur during dry, windy weather regardless of stand age (Brown 1975) or fuel type. The overriding effect of weather was demonstrated in the large-scale fires that occurred in northwestern Wyoming in 1988.

Two biotic factors that have a great impact on the fire dynamics of lodgepole pine are dwarf mistletoe and the mountain pine beetle. Dwarf mistletoe reduces tree vigor and may increase mortality. Conversely, the type of fire affects the potential for mistletoe infection. A stand thinned by fire may become more susceptible to mistletoe, since mistletoe is most successful in otherwise unstressed trees, such as those in a well-spaced stand (Parmeter 1978). Mountain pine beetle-lodgepole pine interaction differs with habitat type. McGregor and Cole (1985) found that in southeastern Idaho and northwestern Wyoming habitat types, 44 percent of stands in the *Abies lasiocarpa/Vaccinium scoparium* habitat type were infested between 6,500 and 8,500 ft (1,890 and 2,590 m); 92 percent were infested in the *Abies lasiocarpa/Pachistima myrsinites* habitat type between 6,500 and 7,800 ft (1,890 and 2,377 m) and 64 percent were infested in the *Pseudtosuga menziesii/Calamagrostis rubescens* habitat type between 6,000 and 7,800 ft (1,829 and 2,377 m).

The relationship between fire, lodgepole pine, and the mountain pine beetle has been well summarized by Amman (1977):

Role of Mountain Pine Beetle Where Lodgepole Pine Is Seral

Absence of fire: Lodgepole pine stands depleted by the beetle and not subjected to fire are eventually succeeded by the more shade-tolerant species consisting primarily of Douglas-fir at the lower elevations and subalpine fir and Engelmann spruce at the higher elevations throughout most of the Rocky Mountains. Starting with a stand generated by fire, lodgepole pine grows at a rapid rate and occupies the dominant position in the stand. Fir and spruce seedlings also established in the stand grow more slowly than lodgepole pine.

With each infestation, the beetle kills most of the large, dominant lodgepole pines. After the infestation, both residual lodgepole pine and the shade-tolerant species increase their growth. When the lodgepole pines are of adequate size and phloem thickness, another beetle infestation occurs. This cycle is repeated at 20- to 40-year intervals depending upon growth of the trees, until lodgepole pine is eliminated from the stand.

The role played by the mountain pine beetle in stands where lodgepole pine is seral is to periodically remove the large, dominant pines. This provides growing space for subalpine fir and Douglas-fir, thus hastening succession by these species. The continued presence of the beetle in these mixed-species stands is as dependent upon fire as that of lodgepole pine. Without it, both are eliminated.

Presence of fire: Where lodgepole pine is seral, forests are perpetuated through the effects of periodic fires (Tackle 1965). Fires tend to eliminate competitive tree species such as Douglas-fir, the true firs, and spruces. Following fire, lodgepole pine usually seeds in abundantly. Serotinous cones attached to the limbs of the tree open because of the intense heat of the fire and release their seed (Clements 1910; Lotan 1975).

Large accumulations of dead material caused by periodic beetle infestations result in very hot fires when they do occur (Brown 1975). Hot fires of this nature eliminate Douglas-fir, which otherwise is more resistant to fire damage than lodgepole pine. The dominant shade-tolerant species are eliminated, resulting in a return to a pure lodgepole pine forest. On the other hand, light surface fires would not be adequate to kill large, thick-barked Douglas-fir and return lodgepole pine to a dominant position in the stand.

Following regeneration of lodgepole pine after fire, the mountain pine beetle-lodgepole interactions would be similar to those described in the absence of fire. A fire may interrupt the sere at any time, reverting the stand back to pure lodgepole pine. However, once succession is complete, lodgepole pine seed will no longer be available to seed the burned

areas except along edges where the spruce-fir climax joins persistent or climax lodgepole pine.

Role of Mountain Pine Beetle Where Lodgepole Pine Is Persistent or Climax

Lodgepole pine is persistent over large acreages, and because of the number of shade-tolerant individuals of other species found in such persistent stands, the successional status is unclear (Pfister and Daubenmire 1975). In any case, lodgepole pine persists long enough for a number of beetle infestations to occur. In such cases and those of a more limited nature when lodgepole pine is climax because of special climatic or soil conditions, the forest consists of trees of different sizes and ages ranging from seedlings to a few over-mature individuals. In these forests, the beetle infests and kills most of the lodgepole pines as they reach larger sizes. Openings created in the stand as a result of the larger trees being killed, are seeded by lodgepole pine. The cycle is then repeated as other lodgepole pines reach sizes and phloem thicknesses conducive to increases in beetle populations.

The result is two- or three-story stands consisting of trees of different ages and sizes. A mosaic of small clumps of different ages and sizes may occur. The overall effect is likely to be more chronic infestations by the beetle because of the more constant source of food. Beetle infestations in such forests may result in death of fewer trees per hectare during each infestation than would occur in even-aged stands developed after fires and in those where lodgepole pine is seral.

Fires in persistent and climax lodgepole pine forests should not be as hot as those where large epidemics of beetles have occurred. Smaller, more continuous deposits of fuel are available on the forest floor. The lighter beetle infestations, and thus lighter accumulations of fuel, would result in fires that would eliminate some of the trees but probably would not cause total regeneration of the stand. This would be beneficial to the beetle because a more continuous supply of food would be maintained. Where large accumulations of fuel occur after large beetle epidemics, fire would completely eliminate the beetle's food supply from vast acreages for many years while the entire stand of trees grow from seedlings to sizes conducive to beetle infestation.

The mountain pine beetle's evolutionary strategies have been successful. It has exploited a niche that no other bark beetle has been able to exploit, that of harvesting lodgepole pine trees as they reach or slightly before they reach maturity. Such trees are at their peak as food for the beetle. Harvesting at this time in the age of the stand maintains the vigor of the stand, and keeps the stand at maximum productivity.

Forest Succession

The hypothetical role of fire in persistent lodgepole pine stands is illustrated in figure 22.

Persistent Lodgepole Pine—Lodgepole pine is essentially the only tree present on the site. Consequently, succession is dominated by lodgepole pine at all stages of development, and even several centuries without fire may not change species composition.

Following a stand-replacement fire, a shrub/herb stage dominates (A). This stage is short-lived because the lodgepole pine seedlings quickly become established and overtop the undergrowth (B). Any fire in the shrub/herb stage will extend its period of dominance. Recurring fire at frequent intervals could conceivably maintain the site in herbs and

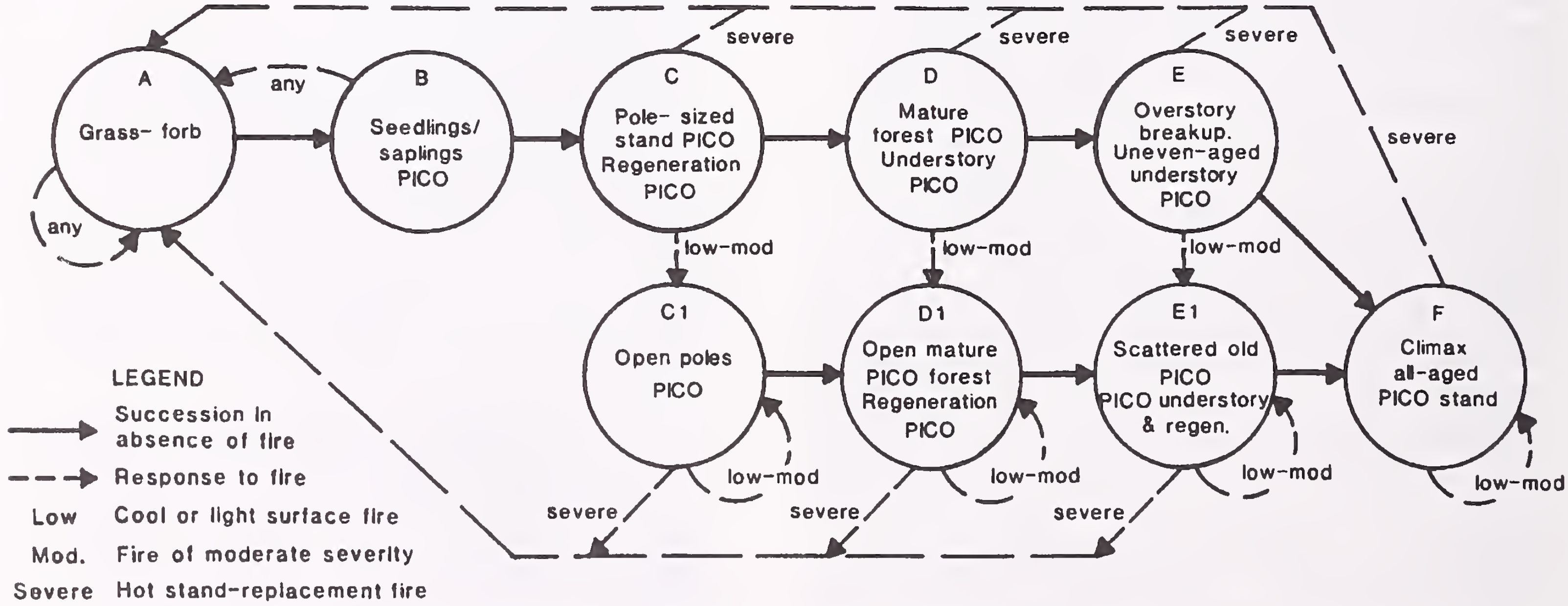

Figure 22—Hypothetical fire-related successional pathways for Fire Group Five habitat types.

shrubs. A fire during the seedling/sapling stage also returns the site to herbs and shrubs. The likelihood of a fire at this stage is not great on most sites.

The effect of a fire during the pole stage depends on fire severity. A cool to moderate fire thins the stand (C2) while severe fire destroys it. Because pole-sized lodgepole pine frequently bear serotinous cone crops, periodic fire at this stage can result in a fire-maintained lodgepole pine stand. The effect of fire in a mature lodgepole forest (D1) is essentially the same as in the pole stand. The probability of a severe stand-removing fire greatly increases as the mature stand starts to break up and an understory of climax species develops (E1). It is usually at this stage rather than the climax stage that severe fire occurs.

Seral Lodgepole Pine—Succession in these habitat types differs only slightly from that in lodgepole pine climax types. Lodgepole pine dominates most of the successional process. The major difference in most successional stages is that potential climax species are evident in the understory sooner and there may be only one generation of lodgepole pine that reaches dominance before it is replaced by more tolerant or longer-lived species. The successional process for stands with seral lodgepole pine is described in Fire Groups Three, Six, and Eight.

Fire Management Considerations

Perhaps the primary fire management consideration in this group is protection from unwanted fire during periods of drought and during severe fire weather conditions. At such times fires often crown and become holocausts if the lodgepole stand is ready to burn in terms of its physiognomy and fuel moistures.

Opportunities for fire use are limited in natural stands because of the low fire resistance of lodgepole pine, spruce, and subalpine fir. The other side of this problem is that during "safe" fire weather, it is often difficult to sustain a fire. But low to medium surface fires do occur. Thus there may be opportunities to use prescribed fires to accomplish specific management objectives.

The primary use of prescribed fire in lodgepole pine has been hazard reduction and site preparation in conjunction with tree harvesting and subsequent regeneration. Broadcast burning and pile and windrow burning have been the most often used methods of accomplishing these tasks. Successful broadcast slash burning usually yields increased forage production for big game. Slash disposal of any kind aids big-game movement through these stands. Harvest schedules should be developed and implemented to create age-class mosaics of lodgepole pine. This minimizes the areal extent of stand-destroying fires. Silvicultural practices designed to harvest trees susceptible to mountain pine beetle before the trees are attacked can greatly reduce the threat of severe fires in second-growth stands of lodgepole pine (Cole and Amman 1980). The use of lodgepole pine for firewood, poles, posts, wood chips, and sawlogs may provide opportunities for fuel management-related harvesting.

Schmidt (1987) lists some pros and cons of using fire to treat overstocked small diameter lodgepole pine stands. Some advantages:

- Low-cost method for stand conversion
- Can regenerate new stand with manageable composition and density
- Closely resembles "nature's method"
- By regulating fire intensity, may be able to reduce seed supply and subsequent overstocking
- Usually leaves some shade to enhance seedling survival
- Reduces insect and disease problems
- Usually increases other resource values such as forage
- Can increase availability of nutrients

Some disadvantages:

- An upfront expense
- With poor fire regulation, may just perpetuate the problem by producing another overstocked stand, or it may require the expense of planting or seeding if all seed is burned under the wrong prescription
- Very limited season for prescribed burning on most lodgepole pine sites
- Requires good fire management skills
- If burned too hot on some sites, nutrient capitals, particularly of nitrogen, can be depleted
- May have a temporary loss in esthetic values

Prescribed fire has been suggested as a management tool for controlling dwarf mistletoe. According to Alexander and Hawksworth (1975), prescribed burning, in relation to mistletoe control, can serve two purposes: (1) eliminate infected residual trees in logged-over areas and (2) destroy heavily infected stands on unproductive sites so that they can be replaced by young healthy stands. Not all fires reduce stand infection. A severe, stand-destroying fire will eliminate dwarf mistletoe. Burns that are sporadic or less severe will leave infected trees on the site to quickly spread the parasite to the developing understory. Where an infested stand has been eliminated, but surrounding mistletoe stands remain, infestation will occur but at a less rapid rate (Zimmerman and Laven 1984).

Lotan and Perry (1983) have summarized the various considerations that determine the appropriate

use of fire for site preparation and regeneration of lodgepole pine forests. Silviculturists and fire managers should consult their guide before developing fire prescriptions to regenerate lodgepole pine.

One factor affecting postfire success of lodgepole pine is competition with herbaceous vegetation. Lodgepole pine is a poor competitor, and seedlings compete least well against grass. On the Sleeping Child Burn in the Bitterroot National Forest, MT, where nonnative grass species were seeded following fire, tree seedling attrition on plots where grass cover was less than 1 percent averaged 4 percent annually on north slopes and 5 percent annually on south slopes. On plots where grass cover averaged 29 percent, the comparable rates of mortality were 21 and 29 percent (Schmautz and Williams 1967). Evidence suggests that as growing conditions become less favorable, grass coverage and hence grass competition becomes less important (Clark and McLean 1979; Stahelin 1943).

Habitat type may help determine potential tree seedling establishment. In southern Montana and southeastern Idaho, significant differences were found in the lodgepole pine seed/seedling ratios between three habitat types. Ratios were lowest (fewest seeds to establish one seedling) on an *Abies lasiocarpa/Vaccinium scoparium* (subalpine fir/grouse whortleberry) habitat type when compared with those in the *Pseudotsuga menziesii/Calamagrostis rubescens* (Douglas-fir/pinegrass) and *Pinus contorta/Purshia tridentata* (lodgepole pine/antelope bitterbrush) habitat types. The presence of lodgepole pine in a habitat type is a function of the ease of establishment, the fire (or other disturbance) history, and the rate of succession in the type. The presence of the species only partially reflects where it is most easily established. Lodgepole pine is generally a seral species. Where lodgepole cover is low and that of other seral species is high, lodgepole pine is probably less suited to these sites. Conversely, where lodgepole pine cover is high, as in the *Abies lasiocarpa/Vaccinium scoparium* habitat type, lodgepole pine is the best suited seral species, and easier to regenerate. Nevertheless, *Pinus contorta* habitat types may present special regeneration problems. They are too harsh for other conifer species to establish, and seed/seedling ratios for lodgepole pine are often high. Also, trees on these sites tend to be open-coned, and so do not have a large store of seeds reserved to restock the site if the stand is removed. In a study of a *Pinus contorta/Purshia tridentata* habitat type in southwestern Montana, seed/seedling ratios ranged from 621:1 to 2,160:1 on scarified clearcuts and 1,876:1 to 6,480:1 on unscarified clearcuts. Seed crops were good, but only 3 of 15 years had significant seedling establishment (Lotan and Perry 1983).

Table 11 includes estimates of seed/seedling ratio under different site conditions. They are guidelines and should not be used to substitute knowledge gained in a specific area. The estimates are conservative, and favorable sites may have considerably lower ratios. Data from the Medicine Bow Mountains and Alberta suggest ratios on the order of 100:1 on well-scarified sites.

Table 11—Estimates of lodgepole pine seed:seedling ratios for different site conditions in southwestern Montana (Lotan and Perry 1983)

Representative habitats	Site preparation		
	None or slight[1]	Broadcast burning	Bulldozer scarification
Cool, moist, low to moderate competition (*Abies lasiocarpa/Vaccinium scoparium*)	1,000:1	1,000:1	300:1
Moderate moisture and temperature, heavy competition (*Pseudotsuga menziesii/Calamagrostis rubescens* to *Abies lasiocarpa/Calamagrostis rubescens*)	10,000:1	3,000:1	300:1
Cool and droughty (*Pinus contorta/Purshia tridentata*)	10,000:1	3,000:1	1,000:1
Hot and droughty (south slopes) without excessive competition	2,500:1	3,000:1	10,000:1
Hot and droughty with heavy competition	15,000:1	4,000:1	10,000:1

[1]Including lop and scatter.

In some wildernesses, periodic crown fires play a vital role in natural development of lodgepole pine ecosystems, and their use should be considered when consistent with the need to protect human life, property, and resource values outside wilderness. In many areas where natural fires have been suppressed, forest residues resulting from mountain pine beetle epidemics accumulate until hot fires occur. "...such fires are normally more destructive than one that would have otherwise occurred if fires had not been suppressed, and they tend to perpetuate future extremes in the mountain pine beetle/lodgepole pine/fire interactions" (Cole 1978).

Cole (1978) suggested that fire management programs can be instituted to moderate the mountain pine beetle-lodgepole pine-fire interaction cycle. His premise is that fire management plans can be developed to use fire to "create a mosaic of regenerated stands within extensive areas of timber that have developed." He believes that manager-ignited prescribed fires can create these ecosystem mosaics more effectively.

Guidelines have been developed by McGregor and Cole (1985) to assist forest managers in integrating pest management techniques for the mountain pine beetle with other resource considerations in the process of planning and executing balanced resource management of lodgepole pine forest. The guidelines present visual and classification criteria and methods for recognizing and summarizing occurrence and susceptibility status of lodgepole pine stands according to habitat types and successional roles and important resource considerations associated with them. McGregor and Cole (1985) review appropriate silvicultural systems and practices, including use of fire, for commercial and noncommercial forest land designations including parks, wilderness, and other reserved areas.

FIRE GROUP SIX: MID AND LOWER ELEVATION SUBALPINE FORESTS

Habitat Types, Phases

Abies lasiocarpa/Acer glabrum h.t.-*Pachistima myrsinites* phase (ABLA/ACGL-PAMY), subalpine fir/mountain maple-pachistima phase

Abies lasiocarpa/Arnica cordifolia h.t.-*Astragalus miser* phase (ABLA/ARCO-ASMI), subalpine fir/heartleaf arnica-woody milkvetch phase

Abies lasiocarpa/Arnica cordifolia h.t.-*Picea engelmannii* phase (ABLA/ARCO-PIEN), subalpine fir/heartleaf arnica-Engelmann spruce phase

Abies lasiocarpa/Arnica cordifolia h.t.-*Shepherdia canadensis* phase (ABLA/ARCO-SHCA), subalpine fir/heartleaf arnica-russet buffaloberry phase

Abies lasiocarpa/Arnica cordifolia h.t.-*Arnica cordifolia* phase (ABLA/ARCO-ARCO), subalpine fir/heartleaf arnica-heartleaf arnica phase

Abies lasiocarpa/Arnica latifolia h.t. (ABLA/ARLA), subalpine fir/mountain arnica

Abies lasiocarpa/Berberis repens h.t.-*Carex geyeri* phase, (ABLA/BERE-CAGE), subalpine fir/Oregon-grape-elk sedge phase

Abies lasiocarpa/Berberis repens h.t.-*Berberis repens* phase (ABLA/BERE-BERE), subalpine fir/Oregon-grape-Oregon-grape phase

Abies lasiocarpa/Carex geyeri h.t.-*Carex gereyi* phase (ABLA/CAGE-CAGE), subalpine fir/elk sedge-elk sedge phase

Abies lasiocarpa/Carex rossii h.t. (ABLA/CARO), subalpine fir/Ross sedge

Abies lasiocarpa/Calamagrostis rubescens h.t.-*Pachistima myrsinites* phase (ABLA/CARU-PAMY), subalpine fir/pinegrass-pachistima phase

Abies lasiocarpa/Calamagrostis rubescens h.t.-*Calamagrostis rubescens* phase (ABLA/CARU-CARU), subalpine fir/pinegrass-pinegrass phase

Abies lasiocarpa/Juniperus communis h.t. (ABLA/JUCO), subalpine fir/common juniper

Abies lasiocarpa/Linnaea borealis h.t.-*Vaccinium scoparium* phase (ABLA/LIBO-VASC), subalpine fir/twinflower-grouse whortleberry phase

Abies lasiocarpa/Linnaea borealis h.t.-*Linnaea borealis* phase (ABLA/LIBO-LIBO), subalpine fir/twinflower-twinflower phase

Abies lasiocarpa/Osmorhiza chilensis h.t.-*Pachistima myrsinites* phase (ABLA/OSCH-PAMY), subalpine fir/mountain sweetroot-pachistima phase

Abies lasiocarpa/Osmorhiza chilensis h.t. *Osmorhiza chilensis* phase (ABLA/OSCH-OSCH)), subalpine fir/mountain sweetroot-mountain sweetroot phase

Abies lasiocarpa/Pedicularis racemosa h.t. (ABLA/PERA), subalpine fir/pedicularis

Abies lasiocarpa/Physocarpus malvaceus h.t. (ABLA/PHMA), subalpine fir/ninebark

Abies lasiocarpa/Spiraea betulifolia h.t. (ABLA/SPBE), subalpine fir/white spirea

Abies lasiocarpa/Symphoricarpos albus h.t. (ABLA/SYAL), subalpine fir/common snowberry

Abies lasiocarpa/Thalictrum occidentale h.t. (ABLA/THOC), subalpine fir/western meadowrue

Abies lasiocarpa/Vaccinium globulare h.t.-*Pachistima myrsinites* phase (ABLA/VAGL-PAMY), subalpine fir/blue huckleberry-pachystima phase

Abies lasiocarpa/Vaccinium globulare h.t.-*Vaccinium scoparium* phase (ABLA/VAGL-VASC), subalpine fir/blue huckleberry-grouse whortleberry phase

Abies lasiocarpa/Vaccinium globulare h.t.-*Vaccinium globulare* phase (ABLA/VAGL-VAGL),

subalpine fir/blue huckleberry-blue huckleberry phase

Abies lasiocarpa/Vaccinium scoparium h.t.-*Calamagrostis rubescens* phase (ABLA/VASC-CARU), subalpine fir/grouse whortleberry-pinegrass phase

Abies lasiocarpa/Vaccinium scoparium h.t.-*Vaccinium scoparium* phase (ABLA/VASC-VASC), subalpine fir/grouse whortleberry-grouse whortleberry phase

Abies lasiocarpa/Xerophyllum tenax h.t.-*Vaccinium globulare* phase (ABLA/XETE-VAGL), subalpine fir/beargrass-blue huckleberry phase

Abies lasiocarpa/Xerophyllum tenax h.t.-*Vaccinium scoparim* phase (ABLA/XETE-VASC), subalpine fir/beargrass-grouse whortleberry phase

Picea engelmannii/Arnica cordifolia h.t. (PIEN/ARCO), Engelmann spruce/heartleaf arnica

Picea engelmannii/Hypnum revolutum h.t. (PIEN/HYRE), Engelmann spruce/hypnum

Picea engelmannii/Juniperus communis h.t. (PIEN/JUCO), Engelmann spruce/common juniper

Vegetation

Fire Group Six contains the bulk of subalpine fir and Engelmann spruce habitat types found in the region. Habitat types in this group range from moist to relatively dry, but do not include wet timberline types, which are described in Fire Groups Seven, or cold timberline types described in Fire Group Eight. Lodgepole pine is the dominant seral species in these forests. Douglas-fir is important on warmer exposures on sites with calcareous soils. Engelmann spruce may be a long-lived seral species or a climax or coclimax dominant with subalpine fir. Aspen often persists on the periphery of older stands, or it may exist mixed with conifer species in the early to middle stages of succession. While it is retained in a stand, it has the potential to become a seral dominant after fire (Steele and others 1983).

Undergrowth makeup is variable. Some habitat types may be dominated by shrub growth; in others, shrubs contribute only minor amounts of cover. Seral aspen stands often have a species-rich undergrowth. Commonly occurring shrubs include *Acer glabrum*, *Amelanchier alnifolia*, *Berberis repens*, *Clematis columbiana*, *Juniperus communis*, *Lonicera utahensis*, *Pachistima myrsinites*, *Physocarpos malvaceous*, *Rosa woodsii*, *Rubus parviflorus*, *Spiraea betulifolia*, *Symphoricarpos albus*, *Symphoricarpos oreophilus*, and *Vaccinium globulare*. Graminoids are *Calamagrostis rubescens*, *Carex geyeri*, *Carex rossii*, and lesser amounts of *Poa nervosa*. *Achillea millefolium*, *Arnica latifolia*, *Aster engelmannii*, *Frasera speciosa*, *Galium triflorum*, *Geranium richardsonii*, *Goodyera oblongifolia*, *Hieracium albiflorum*, *Osmorhiza chilensis*, *Ozmorhiza depauperata*, *Pedicularis racemosa*, *Pyrola secunda*, *Silene menziesii*, *Smilacina racemosa*, *Thalictrum fendleri*, *Thalictrum occidentale*, and *Viola adunca* are typical forbs.

Forest Fuels

Live and standing dead fuel can contribute significantly to overall fire hazard in Fire Group Six. Dense spruce and fir understory trees along with low-hanging moss-covered live and dead branches of overstory trees form effective fuel ladders to the overstory crowns. Dead subalpine fir and Engelmann spruce trees have significant amounts of fine fuels in lateral twigs, which often curl against the larger branches or trunk, frequently along the entire length of the tree. Dead trees are often closely intermingled with live vegetation and easily spread fire to overstory crowns during dry weather. Aspen is an important seral component in some stands in Fire Group Six. While it remains important on a site, fire hazard will be lower. As succession proceeds and aspen is replaced by conifers, the fire hazard will also increase (fig. 23).

Oberheu and Mutch (1975) measured fuels in *Abies lasiocarpa/Carex geyeri* and *Abies lasiocarpa/Vaccinium scoparium* habitat types in the Teton Wilderness. They analyzed fuel loadings by stage in stand development (table 12). The "recent burn" stand condition was characterized by moderate to dense stocking of even-aged lodgepole pine seedlings or saplings, 3 to 40 years old. These stands contained heavy loadings of large-diameter, windthrown, fire-killed snags and very little duff. The even-aged lodgepole pine stage was characterized by dense lodgepole, 85 to 140 years old, with closed or nearly closed canopies and evidence of some natural thinning in progress. Decay had reduced the heavy loading of downed material from the previous fire. The transition stands were characterized by mostly mixed overstories of old-age lodgepole pine, 230 to 250 years old, and spruce and subalpine fir. The understory was made up of spruce and fir. In this stage, increasing large-diameter-class fuel loadings over time reflect the breakup of the lodgepole pine stand. Stands designated as spruce-fir had overstories of subalpine fir and scattered, very large spruce, 250 years or more in age. Heavy fuel loads were mostly made up of dead and downed lodgepole pine. Some fuel loading and stand age information is available for the Bridger Wilderness (table 13). Large-diameter fuels are much more prevalent in the younger lodgepole pine stands, whereas duff loading is higher in the spruce- and whitebark pine-dominated stands (Norman 1991).

Figure 23—A Fire Group Six stand where seral aspen is almost completely replaced by tolerant conifers. As aspen drops out of the stand, fire hazard increases with the dominance of more flammable subalpine fir and spruce.

Table 12—Downed fuel loads associated with stands within the *Abies lasiocarpa/Vaccinium scoparium* and *Abies lasiocarpa/Carex geyerii* h.t.'s, Teton Wilderness, WY (Oberheu and Mutch 1975)

		Downed, dead woody fuel by size classes (inches)							
Stand condition	**Stand age**	**0-¼**	**¼-1**	**1-3**	**3+ Sound**	**3+ Rotten**	**Total**	**Litter**	**Duff**
	Years	*Tons per acre*							
Recent burn	3 - 40	0.1	0.3	1.1	25.3	17.0	43.8	0.5	10.1
Even-aged lodgepole	85 - 140	.1	.5	1.0	4.2	2.8	8.6	1.2	28.9
Transition	230 - 250	.2	.8	1.9	12.2	9.5	24.6	1.5	33.2
Spruce-fir	250+	.2	.9	2.3	10.2	14.2	27.8	1.0	37.3

Dead and downed woody fuel loadings on lower subalpine habitat types in Montana and northern Idaho averaged between 20 and 25 tons/acre (45 and 56 metric tons/hectare) (Brown and See 1981). Loads ranging between 1 and 80 tons per acre (2 and 180 metric tons/hectare) were inventoried by Fischer (1981) in Montana Engelmann spruce-subalpine fir cover types.

Clagg (1975) looked at fuels in subalpine forests of Rocky Mountain National Park and the Roosevelt National Forest in Colorado. The number of standing snags left after a fire declined through stand age 74. The number subsequently rose as the canopy closed and competition mortality occurred. Larger snags (greater than 6 inches [15cm] d.b.h.) dominated in stands aged 8 to 74 years. A second peak

Table 13—Average fuel loadings and stand condition measured in the Bridger Wilderness, Bridger-Teton National Forest, WY 1975 (Norman 1991)

Size class	Cover type: Lodgepole (70 plots)	Spruce (60 plots)	Whitebark (35 plots)
Inches	*Tons/acre*		
0-0.25	0.096	0.119	0.081
0.25-1.0	.050	.681	.251
Litter	.57	.498	.23
1-3	2.06	.697	.701
Dead grass/forb	.004	.002	.006
Cones	.16	.213	.25
Total <3	2.94	2.212	1.52
3+ sound	15.04	3.254	1.30
3+ rotten	9.54	5.06	1.88
Duff	6.53	18.34	11.29
Dead brush	.014	.0005	.0
Total dead	34.06	28.87	15.99
Live grass/forb	.118	.131	.218
Live brush	.13	.006	.0
Total fuel load	34.31	29.00	16.20

Conifer stand condition

Species	Age (yr) Average	Max	Std. Dev.	Crown base height (ft) Average	Max	Std. Dev.
Lodgepole	67	218	81	9.4	35	10.2
Spruce	124	300	133	7.9	18	5
Whitebark	224	241	15	11.9	3	0

at around stand age 200 was dominated by small snags (less than 6 inches d.b.h.). These probably resulted from competition. By age 250, large snags again dominated until the next fire. Fuel moisture was kept high by typical wet summer conditions. Clagg concluded that fuels in these subalpine stands could be considered hazardous only during extended drought or periods of strong winds.

In the same Colorado study, 99 percent of the total downed woody fuel loading was accounted for by 1,000-hour time lag fuels. The load ranged from 10 to 37 tons per acre (22 to 83 metric tons/hectare). Immediately after a fire, loads measured 19 tons per acre (43 metric tons/hectare). Stands 400 years old had loads of 33 tons per acre (74 metric tons/hectare). Sound 1,000-hour fuels remained fairly constant or exhibited a slight downward trend over time. In contrast, the importance of rotten 1,000-hour fuels increased as stands matured. An observed increase in total loading was almost entirely accounted for by this increase in the rotten fuels. Fuels in smaller size classes appeared to change little over time. Fine fuels, important for fire spread, were discontinuous and not very abundant.

A combination of deep duff and large amounts of dead, rotten fuel can result in hot, smoldering surface fires during unusually dry conditions. Ladder fuels are common and fire can easily spread to the tree crowns. Fire does not usually spread to other fuel types from spruce-fir. Intense fire behavior where fire can spread to other fuel types may occur late in the fall when vegetation is cured and dry. Trees torch and fire spreads by short-range spotting. Wind may push fire through crowns independent of surface fire. Under extended drought, ground fuels will dry sufficiently to carry rapidly spreading high-intensity fire. Under these conditions, fires have the potential to burn large acreages (U.S. Department of the Interior 1991).

Even if surface fires do not crown, there is a good chance that the overstory spruce and subalpine fir will be killed by cambium heating. Shallow-rooted spruce or fir may be killed outright or injured by duff fires, which leaves them susceptible to insects, disease, or windthrow. Because of the predominantly cold, moist conditions in subalpine forests, even stands with relatively heavy fuel loads may not experience fires for many decades or centuries.

Role of Fire

Historically, fire led to dominance by one or more seral species, created openings in dense stands, and created a mosaic of different ages and species compositions in spruce-fir forests.

Where aspen is seral, encroachment of conifers make stands increasingly susceptible to fire as succulent forbs are succeeded by woody fuel and litter. Conifer-to-conifer succession shortens the period of fuel buildup and the interval between fires when compared to aspen-to-conifer succession (Pfister 1972). Generally moist conditions and slower rates of fuel accumulation make large fires in subalpine forests unlikely except during periods of drought and high wind. Most fires that consume significant acreage in subalpine fir and spruce habitats are severe fires during the dry, windy conditions that accompany cold fronts (Crane 1982; Fryer and Johnson 1988).

Lightning starts fewer fires in subalpine habitat types than it does in drier, warmer forest types. In the Northern Rocky Mountains, Arno (1980) estimated fire intervals of 50 to 130 years for subalpine fir habitat types. He believed that burning by Native Americans may have contributed to the relatively short fire-free interval of 57 years in the northern Bitterroot Mountains of Montana. Hawkes (1979) estimated mean fire return intervals (MFRI) in Kananaskis Provincial Park, AB. Different MFRI's were obtained when data were analyzed by elevation and aspect. North-facing stands' MFRI was 187 years. The shortest interval by aspect measured was 93 years, found on east-facing slopes. Lower subalpine forests, mostly dominated by lodgepole pine, gave an MFRI of 90 years, upper subalpine forests' MFRI was 153 years. The Park as a whole had a natural fire regime where large (2,500 acres [1,000 ha]), medium- to high-intensity fires occurred at infrequent intervals. Between 1712 and 1920, such a fire occurred, on average, every 21 years. In the Medicine Bow Mountains of southeastern Wyoming, stand-replacement fires appear to be more frequent, albeit still relatively rare, on upland sites. Fire returned to upland slopes every 300 to 350 years, maintaining lodgepole pine as the dominant species. Ravines appeared to burn only once in every 350 to 500 years (Romme and Knight 1981). Lodgepole pine-dominated subalpine fir forests in the Little Firehole River drainage of Yellowstone National Park experienced large (10 acres [4 ha]), stand-replacement fires probably once in 300 to 350 years (Romme 1982). Relatively few acres appear to have burned during the last 300 to 400 years in central and southern Rocky Mountain subalpine forests (Alexander 1987).

Forest Succession

The seral species involved in succession depends on habitat type, geographic location, and availability of seed or other reproductive means (for instance, aspen roots). Pfister (1972) described the structural and successional characteristics of subalpine forests in neighboring Utah. He found that succession after fire or other disturbance proceeded more slowly on less favorable sites, and seral species retain dominance for long periods. Romme and Knight (1981) estimated it took mesic upland slopes dominated by lodgepole pine 400 years to become mature spruce fir forests in a drainage on the Medicine Bow Forest. In more moist ravines, spruce and fir regeneration probably proceeded without the intervening pine stage. In these more favorable conditions, mature subalpine forests took 200 to 300 years to develop. Where spruce is a major stand component in early seral stages, it tends to dominate late successional and climax stands. Some consider it a coclimax, rather than a persistent seral species, although it appears to be unable to regenerate in its own litter (Mauk and Henderson 1984). On harsh sites, aspen acts as a nurse tree for conifer regeneration. Where livestock or wild ungulates remove aspen, conifer establishment may be hindered. Generalized successional patterns are illustrated in figure 24. More detailed pathways are illustrated in figures 25, 26, and 27. Letters in this section refer to these latter figures.

Succession With Lodgepole Pine—On sites where lodgepole pine is the sole or dominant seral species, after a stand-replacing fire an initial herb/shrub community becomes established (A). Fires of any severity maintain this state. Where lodgepole pine is serotinous, this stage is quickly followed by a dense stand of even-aged seedlings and saplings (B). Lodgepole pine with nonserotinous cones may also reestablish relatively rapidly when there is an adequate outside seed source. Nonserotinous stands are often less dense, and the seedlings may invade over a period of several years, giving the stand an uneven-aged character. A more open stand (B1) may include Englemann spruce. Subalpine fir is not usually present at this stage. If pine regeneration is dense, other conifer seedlings are probably crowded out (C). Low to moderate fire may open the stand and permit regeneration of fir and spruce as well as

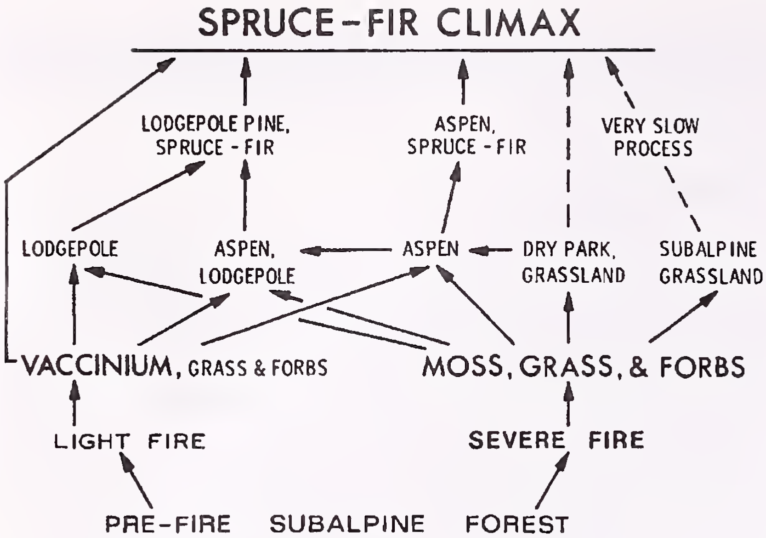

Figure 24—Generalized patterns of succession in Rocky Mountain subalpine forests (Stahelin 1984).

more pine (C1). Without fire, a dense pole stand becomes a crowded mature stand of pine (D). Stem density is somewhat reduced by competition-induced mortality. The understory in the pole or mature state is sparse. Low to moderate fire in the mature state can open the stand and permit further development of a mixed species understory. The stand eventually breaks up due to disease, decadence, or beetle kill (E). Fir and spruce are able to invade openings. Stands with a dying lodgepole pine overstory and fir-spruce understory are susceptible to severe fire because of their typically heavy fuel loads. Severe fires recycle the stand. If no fire occurs during breakup, the stand is dominated by climax fir and spruce (G).

Moderate fires in mixed stands (E1) kill most of the tolerant conifers but can spare some of the

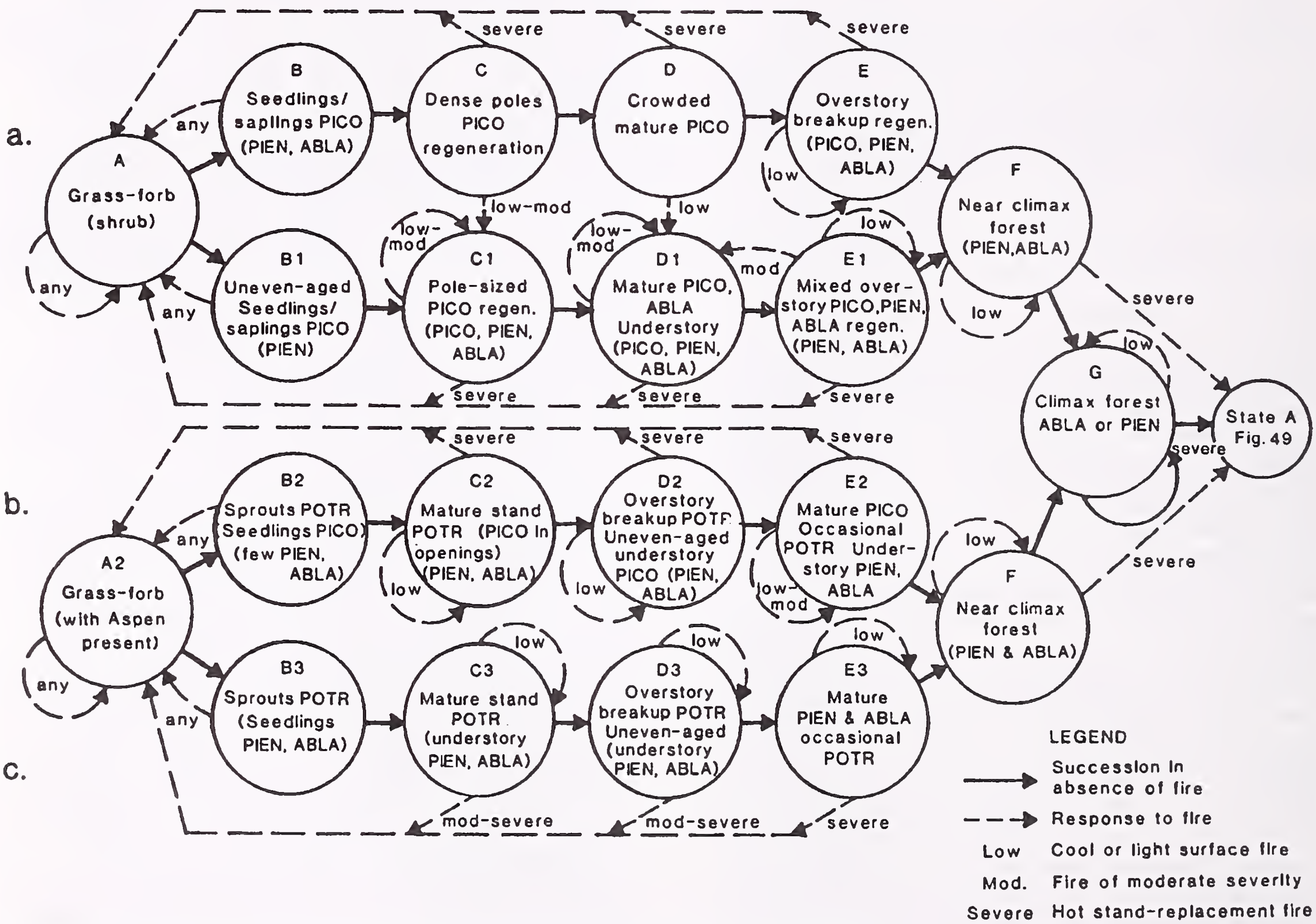

Figure 25—Hypothetical fire-related successional pathways for Fire Group Six habitat types where lodgepole pine or aspen are the major seral dominants.

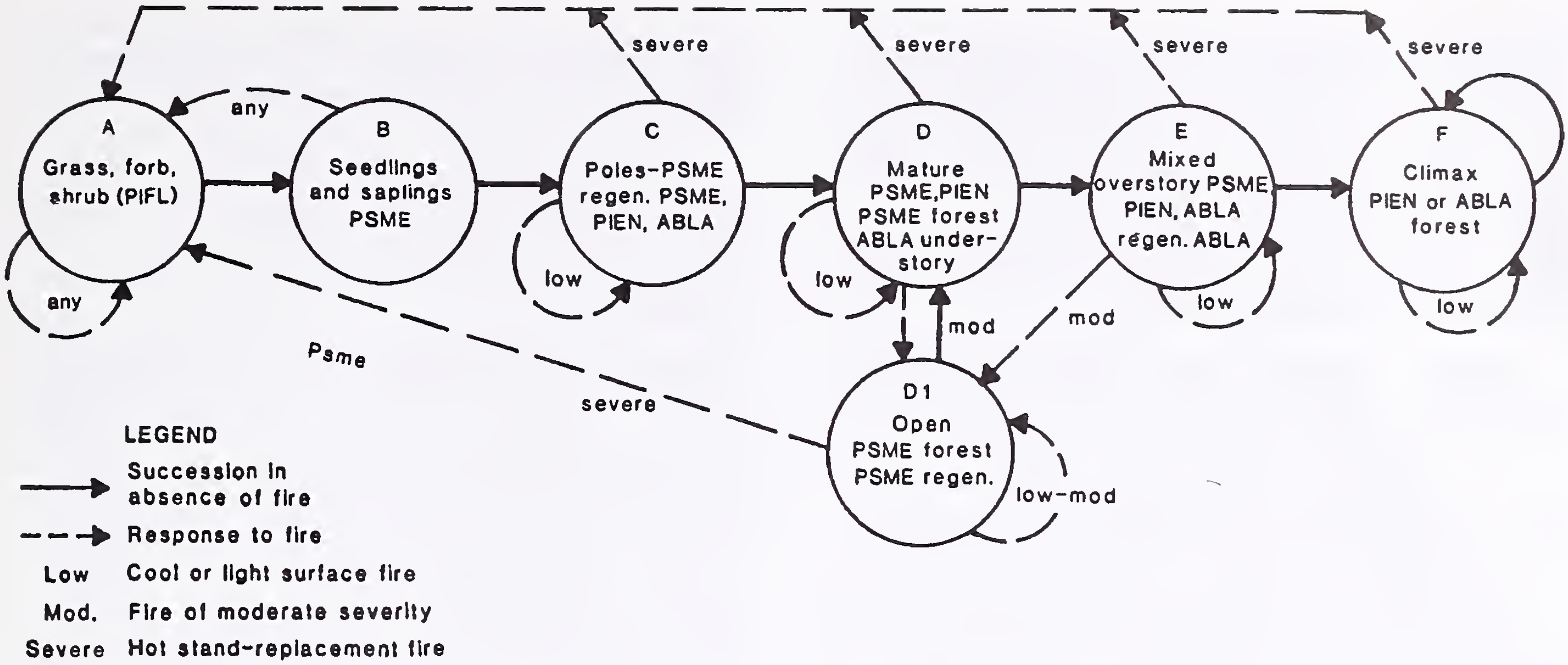

Figure 26—Hypothetical fire-related successional pathways for Fire Group Six habitat types where Douglas-fir is the major seral dominant.

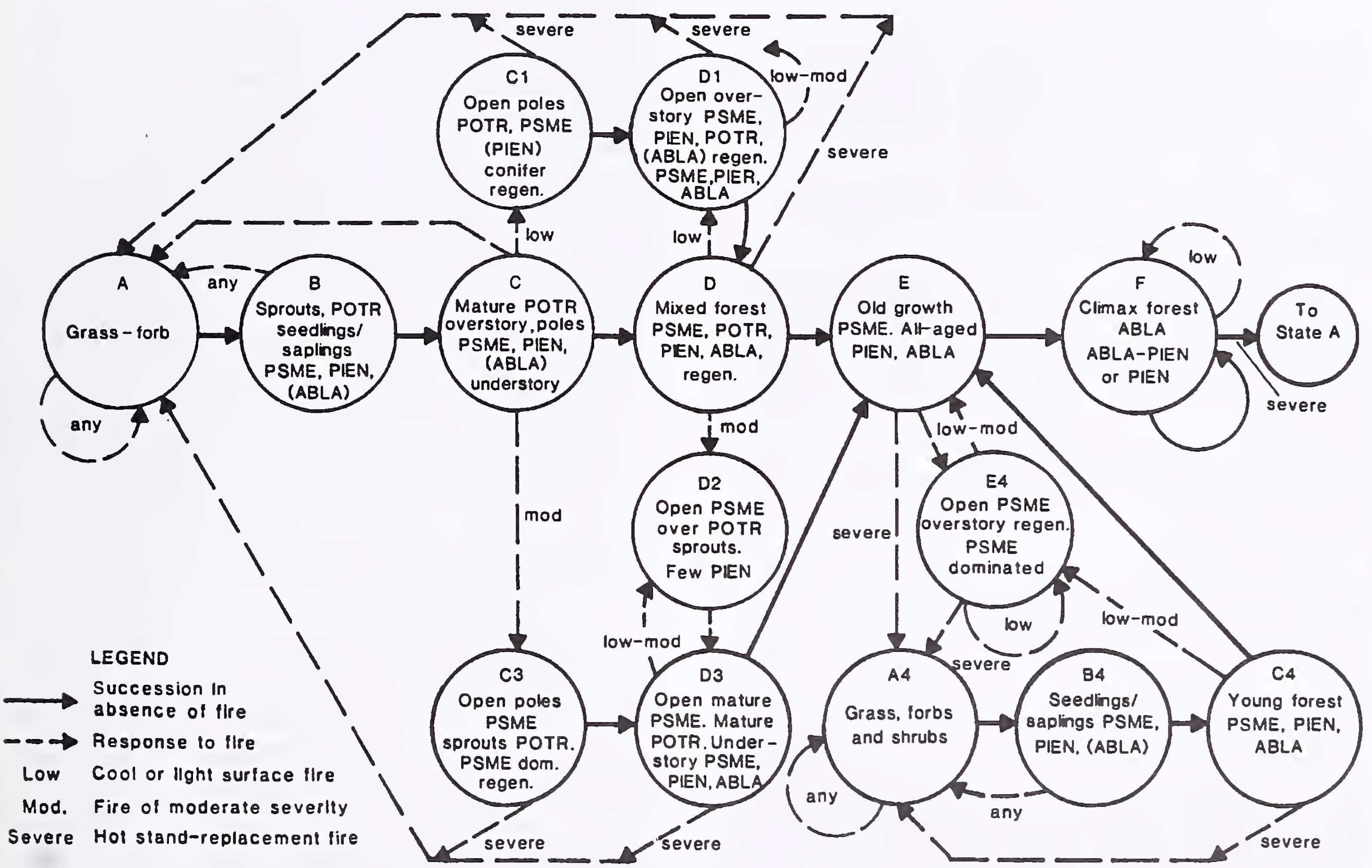

Figure 27—Hypothetical fire-related successional pathways for Fire Group Six habitat types where succession is characterized by a mixture of species.

lodgepole pine. The overstory is then again made up of scattered lodgepole pine (D1). At near-climax or climax (F,G), a severe fire returns the stand to an herb/shrub state. Low surface fires reduce fuels and expose mineral soil for regeneration. If a lodgepole pine seed source is not available, a severe fire initiates a successional process in which spruce and fir alone dominate seral stands. Fire ordinarily occurs before this condition is reached.

Succession With Lodgepole Pine and Aspen—Where aspen and lodgepole occur together in a stand, aspen resprouts and lodgepole pine seedlings may both become established in an herb/shrub field after fire (B2). Aspen grows quickly, however, and soon overtops lodgepole pine. Pine seedlings tend to be restricted to openings where there are no suckering aspen roots (C2). Spruce and subalpine fir regeneration may occur beneath the aspen or lodgepole pine canopy. Low fires open the stand, favoring lodgepole pine seedling establishment, or possibly aspen suckering if enough aspen stems are killed to stimulate sprouting. Without fire, the aspen overstory eventually breaks up (D2). A mixed conifer stand develops with lodgepole pine in the overstory and spruce and fir in the understory (E2). Low to moderate fires maintain this stand, and all species regenerate in the openings. Aspen survives in occasional patches. As the stand approaches climax conditions, lodgepole pine drops out of the stand (F). Severe fires at near-climax or climax return the stand to the shrub/herb state.

Succession With Aspen Only—Where aspen is present, it usually resprouts after a brief herb stage (A2). Resprouting shrubs and aspen may both appear the first growing season after fire. Any fire can kill resprouts. Spruce and fir seedlings are shade tolerant and able to establish beneath a canopy of aspen in any stage of development (B3 through E3). Seedlings may be smothered in aspen leaf litter, however, slowing their invasion into the stand. A low surface fire may kill most conifer regeneration, but it can also damage aspen stems. If only scattered stems are killed, suckering may not be stimulated. An influx of conifers in the understory may occur in the gaps.

Moderate to severe fires return the site to herbs in any successional stage. The site is quickly repopulated by suckers. Spruce and fir reestablish in openings. Without fire, the conifer understory continues its development and eventually replaces the shorter-lived aspen, which is unable to propagate successfully in the shade (D3). Severe fires in the mature conifer stand cause a return to the herb stage. If remnant aspen are left, some resprouting may occur. Where most or all aspen stems are dead or decadent, fire does not cause sufficient suckering for regeneration because the root system is also weakened. Without fire, conifer density will continue to increase over time (E3,F). Conifers may become dominant on many sites in 200 to 400 years (Bartos and others 1983; DeByle and others 1987). Climax stands old enough to be pure spruce and fir are rare. If fire occurs in one of these sites, lack of pine or aspen will mean the climax dominants also dominate seral stages.

Succession With Douglas-fir—Where Douglas-fir is the dominant seral species, an unforested condition may be maintained by fire of any severity if it occurs in the herb/shrub or the seedling-sapling states (A,B). At other stages of stand development, severe fire will have the same effect. Low fires occurring in the pole through climax stages would not change stand condition much. Where spruce is an important species, it may be killed by even low fires because of its shallow roots. Any opening caused by spruce mortality is quickly recolonized by Douglas-fir, subalpine fir, and spruce. Moderate fires are not likely to occur until there has been some buildup of understory dead and live fuels (D). If there is a moderate fire in the mature stage, Douglas-fir will be favored because it is the most fire resistant. An open Douglas-fir overstory with Douglas-fir in the understory results. Low to moderate fire provides mineral seedbed for regeneration, resulting in a Douglas-fir overstory with Douglas-fir regeneration beneath (D1). If fire does not occur, subalpine fir and spruce also establish beneath the Douglas-fir and form an understory (E). After several centuries, an undisturbed stand converts to pure spruce or fir (F). Pure stands are rare because of the potential for fire and the longevity of Douglas-fir.

Douglas-fir may also share seral dominance with aspen (no diagram). After a stand-replacement fire, both aspen sprouts and Douglas-fir seedlings may establish on the site. Because aspen grows more quickly, however, it will probably dominate the site until maturity. In the understory, Douglas-fir may occur with climax spruce or fir. Low or moderate fires open the aspen stand and permit more conifer regeneration as well as aspen sprouting. Once the aspen begins to break up, Douglas-fir may seed into openings and form a multistoried stand with the climax tolerant species in the understory. Over a long period of time without fire, Douglas-fir will be replaced by spruce and fir.

Succession With Mixed Species—Forest succession in the absence of fire proceeds from a transitional shrub/herb state to a seedling and sapling state (B1) in which Douglas-fir, lodgepole pine, spruce, and often subalpine fir are present. Any fire will return the site to shrubs and herbs. In the continued absence of fire, a mixed-species pole stand

will develop (C1) and eventually a mature mixed forest (D1). Douglas-fir and lodgepole pine often dominate the pole and mature states, but spruce is a vigorous competitor on some sites. In the unlikely event that fire-free succession continues, a near-climax state (F1) occurs where spruce and subalpine fir dominate the overstory with scattered, long-lived Douglas-fir trees. The understory of such a stand would be dominated by spruce and fir. Eventually, without fire, the theoretical climax (G1) dominated by either spruce or subalpine fir occurs. Severe fires in the pole, mature, near-climax, and climax states will probably remove the stand and temporarily return the site to the shrub/herb state. Lodgepole pine is absent from succession following severe or moderate fires in the near-climax or climax states. The effect of low to moderate fires varies by state. A low to moderate fire in the pole state favors Douglas-fir over pine, spruce, and subalpine fir. Such fires result in an open Douglas-fir stand with a few lodgepole pine. If cone-bearing lodgepole pine are in the prefire stand, pine probably dominates the regeneration. In the absence of fire, such a stand progresses to a mature Douglas-fir forest with a lodgepole pine understory (D3). Over time, lodgepole pine grows into the overstory and may dominate the stand, except for scattered, veteran Douglas-fir, with spruce and subalpine fir in the understory. Low to moderate fire sets back climax species regeneration. Low to moderate fire does little but thin the understory in a stand dominated by seral Douglas-fir. Moderate fire can remove most trees from a stand dominated by lodgepole pine. Pole-sized Douglas-fir and lodgepole pine are more sensitive to fire damage than mature trees. Low to moderate fires thin trees in the pole state (C1). A second fire in the resulting open stand (C2) may return the stand to the herb/shrub condition. But this is unlikely because of reduced fuel loads. Moderate fires in the mature state remove lodgepole pine, spruce, and subalpine fir and leave the site dominated by open Douglas-fir. Low to moderate fires maintain this condition. In near-climax stands (F1) low to moderate fires have a similar result, except that lodgepole pine is no longer a member of the community and will not be part of further succession (B2,C3,D4). Low to moderate fires maintain an open Douglas-fir stand (E1).

Fire Management Considerations

Fire can sanitize and reduce fire hazard in stands, provide good seedbed conditions for spruce in areas where it is an important timber species, and regenerate aspen for wildlife and livestock browse. Fire produces a vegetational mosaic favorable for wildlife and can improve water yield by converting dense conifer stands to aspen or to shrub and herbaceous cover.

Fire protection is usually an important consideration during severe burning conditions, especially where timber production is an objective. At other times, fires may be of low to moderate severity and result in only moderate damage or no damage to understory trees, despite the relatively low fire resistance of some of the species present. Large, overstory Douglas-fir should easily survive fire of low to moderate intensity.

Fire has been used to remove stands of mistletoe-infested lodgepole pine (Chonka 1986) and to reduce the food supply for spruce beetles in cull logs or windthrows (Wright and Bailey 1982).

Fire can be used to dispose of logging slash on harvest areas, but broadcast burning for site preparation may be hampered by high duff moistures and the limited number of acceptable burning days during traditional spring and fall burning periods. Consequently, summer burning may produce better results, and has become common in some areas (Crane and Fischer 1986). Debris left on exposed sites will increase regeneration success of spruce (Wright and Bailey 1982).

FIRE GROUP SEVEN: MOIST OR WET SUBALPINE FIR AND ENGELMANN SPRUCE HABITAT TYPES

Habitat Types, Phases

Abies lasiocarpa/Actaea rubra h.t. (ABLA/ACRU), subalpine fir/baneberry

Abies lasiocarpa/Calamagrostis canadensis h.t.-*Ledum glandulosum* phase (ABLA/CACA-LEGL), subalpine fir/bluejoint reedgrass-Labrador-tea phase

Abies lasiocarpa/Calamagrostis canadensis h.t.-*Vaccinium caespitosum* phase (ABLA/CACA-VACA), subalpine fir/bluejoint reedgrass-dwarf huckleberry phase

Abies lasiocarpa/Calamagrostis canadensis h.t.-*Calamagrostis canadensis* phase (ABLA/CACA-CACA), subalpine fir/bluejoint reedgrass-bluejoint reedgrass phase

Abies lasiocarpa/Menziesia ferruginea h.t.-*Menziesia ferruginea* phase (ABLA/MEFE-MEFE), subalpine fir/menziesia-menziesia phase

Abies lasiocarpa/Streptopus amplexicaulis h.t.-*Streptopus amplexifolius* phase (ABLA/STAM-STAM), subalpine fir/twistedstalk-twistedstalk phase

Picea engelmannii/Caltha leptosepala h.t. (PIEN/CALE), Engelmann spruce/elkslip marshmarigold

Picea engelmannii/Carex disperma h.t. (PIEN/CADI), Engelmann spruce/soft-leaved sedge

Picea engelmannii/Equisetum arvense h.t. (PIEN/EQAR), Engelmann spruce/field horsetail

Picea engelmannii/Galium triflorum h.t. (PIEN/GATR), Engelmann spruce/sweetscented bedstraw
Picea engelmannii/Linnaea borealis h.t. (PIEN/LIBO), Engelmann spruce/twinflower
Picea engelmannii/Physocarpus malvaceus h.t. (PIEN/PHMA), Engelmann spruce/ninebark

Vegetation

Fire Group Seven is composed of subalpine fir and Engelmann spruce habitat types occurring in seasonally moist or wet conditions, or where soils are subirrigated and water tables remain high year-round. These include subalpine habitat types usually found adjacent to riparian vegetation, on moist benches, or as stands associated with late-melting snowbanks at higher elevations. Engelmann spruce is a persistent seral or climax species. On some sites, blue spruce may codominate. Lodgepole pine is the other important seral species in several of the types, and Douglas-fir and whitebark pine play considerably more minor roles. Subalpine fir establishment in the spruce habitat types depends on the availability of raised microsites.

Undergrowth vegetation is often lush and diverse, but shrub cover is often scant in many of the types. Shrubs that may occur include *Vaccinium scoparium*, *Sambucus racemosa*, *Ribes montigenum*, *Lonicera involucrata*, *Ledum glandulosum*, *Vaccinium acespitosum*, and in the PIEN/CALE type, *Kalmia polifolia*, *Phyllodoce empetriformis*, and *Vaccinium occidentale*. There is a diversity of tall and low forbs on these sites. Forbs often encountered include *Actaea rubra*, *Streptopus amplexifolius*, *Erigeron peregrinus*, *Equisetum arvense*, *Epilobium angustifolium*, *Arnica cordifolia*, *Achillea millefolium*, *Geranium richardsonii*, *Pyrola secunda*, *Mertensia ciliata*, *Saxifraga arguta*, *Senecio triangularis*, *Trollius laxus*, *Pyrola asarifolia*, and *Osmorhiza depauperata*. *Glyceria elata*, *Deschampsia caespitosa*, *Calamagrostis canadensis*, *Carex rossii*, *C. disperma*, *Luzula parviflora*, *Bromus ciliatus*, and *Elymus glaucus* are typical graminoids.

Forest Fuels

Fuels in moist subalpine fir forests resemble those described in Fire Group Six. Thousand-hour time lag fuels make up the bulk of the fuel loading. The potential for Engelmann spruce to reach large diameters on these sites may result in a greater average diameter of the large woody fuels. Fires are infrequent due to the moist environment and lush shrub and herb component (fig. 28). There may be much rotten material and duff on the forest floor. In colder, higher elevation habitat types, the proportion of sound to rotten woody fuel may be greater because of slow decomposition rates. Fire Group Seven stands are susceptible to severe burns when droughts occur. Stands may be killed by either duff fire or crown fires that encroach from surrounding stands. Thin bark and shallow roots make spruce especially susceptible to mortality from hot surface fires that consume organic layers around trees.

Role of Fire

Fire history is poorly understood in these types. As a rule, fire is a less frequent disturbance on moist or wet sites. In this fire group, habitat types that occur on benches, such as *Picea engelmannii / Galium triflorum*, may be somewhat more likely to burn than the truly hydric types (Scott n.d.). Although it does not occur as often, fire may be more severe in its effects because of higher site productivity and because rhizomes and seeds of undergrowth species may be in organic layers of the soil, making them susceptible to fire-kill as duff and litter are consumed. At higher elevations, slower decomposition rates increase the amount of available fuels on a site. Low, smoldering fires of restricted area probably occur most often. This type of burn removes one or a small group of trees rather than an entire stand or drainage. Severe fires occur only during extremely dry conditions, when fires starting on upland sites are of high intensity and more likely to spread. Crane (1982) reported estimates of 325 to 335 years with a a variance of 50 years as the fire return interval in 3 moist spruce habitat types on the Shoshone National Forest. Romme and Knight (1981) found intervals of 300 to 400 years between fires in drainage bottoms compared to 300 years for drier upland sites of the Medicine Bow National Forest in southwestern Wyoming. The mean fire-free interval for a moist *Abies lasiocarpa/Clintonia uniflora* habitat type in northwestern Montana was estimated to be 130 years (Sneck 1977). Cooper (1975) commented that on this *Picea engelmannii-Abies lasiocarpa/Galium triflorum* type, stands were dominated by later successional stages, attesting to the relative infrequency of fire and a rapid rate of succession.

Forest Succession

Fires of moderate severity are probably much less common in these types than either occasional low-severity burns or, rarely, a severe fire. Stands are usually either too wet to burn well, or dry out during prolonged drought and become susceptible to stand-replacement fires. The hypothetical results of fire at different points in the development of Group Seven stands is illustrated in figure 29. Subsequent discussion in this section refers to figure 29.

Figure 28—Fire Group Seven forests often have a lush undergrowth of forbs and grasses. Fires are infrequent because of the moist conditions, but may be severe when they do occur because of the relatively high productivity of these sites (Engelmann spruce/sweetscented bedstraw stand, Targhee National Forest).

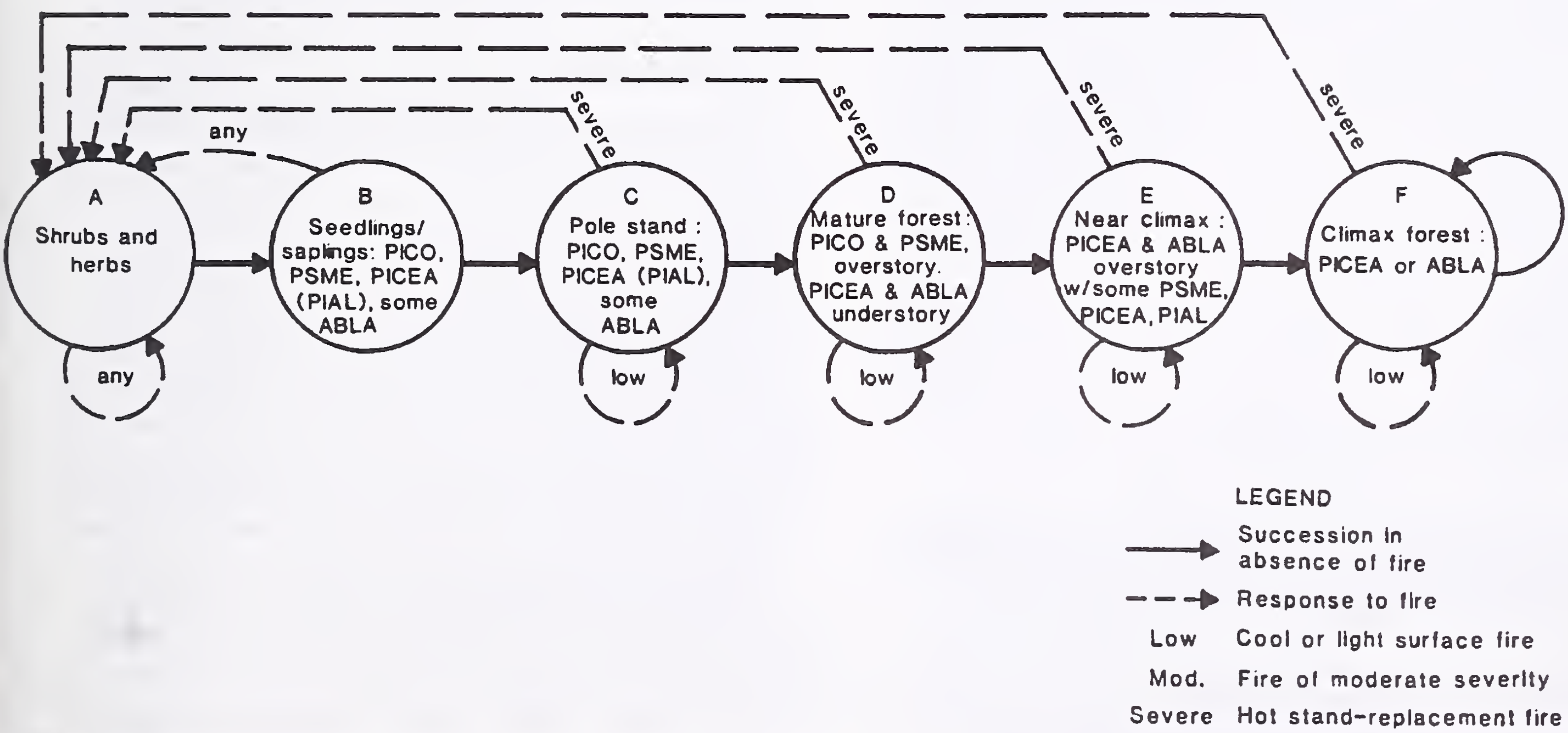

Figure 29—Hypothetical fire-related successional pathways for Fire Group Seven habitat types. PICEA may be either PIEN or PIPU.

Following a stand-replacement fire, there is a brief herb stage followed rapidly by shrub resprouting (A). Fires that remove much of the duff will also remove shallow-rooted undergrowth species. Shrubs and herbs, resprouting from deep-seated roots or rhizomes, and annual plants will dominate the early postfire site. Conifer seedlings may also colonize the newly exposed mineral soil (B). Any fire in this stage recycles the stand to a shrub/herb state. In the pole stage (C), rapidly growing lodgepole pine may overtop other, slower growing conifers present. The mature forest (D) consists of a lodgepole pine overstory, possibly with some Douglas-fir, and a multiaged understory of spruce and fir. In the near-climax state (E), the seral overstory is gradually replaced by spruce and fir. At climax (F), spruce and subalpine fir alone remain on the site. Low fires at any stage open stands and provide microsites for seedling establishment. Engelmann and blue spruce are shallowly rooted trees, and even low fires may kill trees outright or weaken roots and make trees susceptible to later windfall. Unusually hot, windy weather may reduce fuel moistures enough to sustain a severe fire. At all stages the site will then return to a treeless condition.

Fire Management Considerations

Management of the habitat types in Fire Group Seven is limited by their restricted distribution and fragility. On wet sites, removal of the overstory may raise the water table, increase soil erosion, and make shallow-rooted spruce susceptible to windthrow (Mauk and Henderson 1984). Windthrow may be mitigated as long as dead trees remain standing. At higher elevations, spruce regeneration may suffer solarization if there is inadequate cover on the site.

Management objectives for these sites are often oriented toward nonconsumptive uses such as watershed protection and wildlife habitat. On some sites, the disturbance associated with modern fire suppression may result in more lasting damage than fire would cause. Consequently, the appropriate fire management policy may be one that allows certain ignitions to burn according to a predetermined fire management prescription (Fischer 1978).

FIRE GROUP EIGHT: COLD, UPPER SUBALPINE AND TIMBERLINE HABITAT TYPES

Habitat Types, Phases

Abies lasiocarpa/Luzula hitchcockii h.t.-*Vaccinium scoparium* phase (ABLA/LUHI-VASC), subalpine fir/smooth woodrush-grouse whortleberry phase

Abies lasiocarpa/Ribes montigenum h.t.-*Pinus albicaulis* phase (ABLA/RIMO-PIAL), subalpine fir/mountain gooseberry-whitebark pine

Abies lasiocarpa/Ribes montigenum h.t.-*Ribes montigenum* phase (ABLA/RIMO-RIMO), subalpine fir/mountain gooseberry-mountain gooseberry phase

Abies lasiocarpa/Vaccinium scoparium h.t.-*Pinus albicaulis* phase (ABLA/VASC-PIAL), subalpine fir/grouse whortleberry-whitebark pine phase

Picea engelmannii/Ribes montigenum h.t. (PIEN/RIMO), Engelmann spruce/mountain gooseberry

Picea engelmannii/Vaccinium scoparium h.t. (PIEN/VASC), Engelmann spruce/grouse whortleberry

Pinus albicaulis/Carex geyeri h.t. (PIAL/CAGE), whitebark pine/elk sedge

Pinus albicaulis/Carex rossii h.t.-*Pinus contorta* phase (PIAL/CARO-PICO), whitebark pine/Ross sedge-lodgepole pine phase

Pinus albicaulis/Carex rossii h.t.-*Carex rossii* phase (PIAL/CARO-CARO), whitebark pine/Ross sedge-Ross sedge phase

Pinus albicaulis/Festuca idahoensis h.t. (PIAL/FEID), whitebark pine/Idaho fescue

Pinus albicaulis/Juniperus communis h.t.-*Shepherdia canadensis* phase (PIAL/JUCO-SHCA), whitebark pine/common juniper-russet buffaloberry

Pinus albicaulis/Juniperus communis h.t.-*Juniperus communis* phase (PIAL/JUCO-JUCO), whitebark pine/common juniper-common juniper

Pinus albicaulis/Vaccinium scoparium h.t. (PIAL/VASC), whitebark pine/grouse whortleberry

Vegetation

Fire Group Eight is made up of high, cold subalpine fir, Engelmann spruce or whitebark pine habitat types that occur at or near timberline (fig. 30). Potential climax species may also serve as the principal seral species on some sites. On others, whitebark pine, lodgepole pine, or occasionally, limber pine may dominate or codominate stands. The mix of seral species depends on substrate, exposure, and moisture conditions. Trees may grow in more or less continuous stands, but at timberline they frequently grow in strings or isolated groups interspersed with alpine vegetation. Trees may be flagged or stunted into krummholz by winter winds.

The short growing season reduces the potential productivity of the understory component. Where the overstory canopy is dense, scattered shrubs and low herbaceous plants may be restricted to gaps. At the timberline, or in open mature stands of whitebark pine, the undergrowth is more lush. On these sites species richness may increase two- to fourfold (Steele and others 1983). Shrubs commonly

Figure 30—A whitebark pine/grouse whortleberry habitat type in Yellowstone National Park. This is a widespread habitat type on high, cold unproductive sites.

associated with high-elevation subalpine forests include *Ribes montigenum*, *Pachistima myrsinites*, *Vaccinium scoparium*, and *Vaccinium caespitosum*. *Juniperus communis* and *Shepherdia canadensis* may be common on some sites. Graminoids typically do not provide extensive cover in these types. *Carex rossii*, *Carex geyeri*, and *Poa nervosa* may attain fair cover on some sites. *Arnica cordifolia*, *Solidago multiradiata*, *Pedicularis bracteosa*, *Pedicularis racemosa*, *Epilobium angustifolium*, and *Pyrola secunda* are forbs encountered in these habitat types.

Forest Fuels

Whitebark pine climax habitat types are often on dry, exposed slopes where trees are widely spaced and there is little in the way of live fuels (fig. 31). Subalpine fir habitat types are more productive and may have a well developed understory of fir that can serve as ladder fuel under extreme fire weather conditions. Downed woody fuels less than 1 inch (2.54 cm) in diameter averaged approximately 1 ton/acre (2.2 metric tons/hectare). The average for woody fuels greater than 1 inch (2.25 cm) was about 3.9 tons/acre (8.7 metric tons/hectare) (see Fire Group Six, table 12). Larger diameter fuels may dominate the downed woody loadings. Fuel loadings in a comparable fire group in Montana averaged 2 tons/acre (4.5 metric tons/hectare) of material one-fourth inch to 3 inches (0.6 to 7.6 cm) in diameter and about 9 tons/acre (20 metric tons/hectare) of fuels over 3 inches in diameter (Fischer and Clayton 1983). Keane and Arno (1989) made measurements in other whitebark-pine-dominated subalpine fir habitat types in western Montana. In undisturbed stands 200 years old or older, they found approximately 1.53 tons/acre (3.34 metric tons/hectare) of fuels 0 to 3 inches in diameter and 17.574 tons/acre (3.94 kg/m^2) of downed woody fuels greater than 3 inches. Of the large fuels, 37 percent was classified as rotten. Duff averaged 0.86 inches (2.18 cm).

The low productivity of these sites decreases the rate of fuel accumulation, and average diameters of large woody fuels will probably be smaller than those on more favorable sites. Countering this trend toward low rates of fuel accumulation is the slow rate of decomposition.

Downed and dead woody fuel loadings are formed by scattered large-diameter downfall resulting from wind and snow breakage, windthrow, and mortality caused by insects or disease. Mountain pine beetle can decimate entire stands of whitebark pine and lodgepole pine. Snags of lodgepole pine fall relatively rapidly and may contribute substantially to the heavy fuel load. Whitebark pine snags are on the average larger than lodgepole pine but remain standing for 50 or more years (Arno 1989), thus adding to the fuel load at a slower rate. The presence of large fuels does not necessarily reflect a serious fire hazard. The mitigating effects of the normally cool, moist site, the short fire season, and the usually sparse and discontinuous fine surface fuels must be considered when evaluating overall fire potential.

In normal fire years, fire is ordinarily restricted to the lightning-struck tree and the area of litter and herbaceous growth around it. Small groups of trees will torch where spruce and fir are a significant part of the understory.

Even these relatively nonflammable stands will burn severely under the right conditions. Chapman (1990) observed fire in whitebark pine stands in the Teton Wilderness during the extreme 1988 fire season. He noted that large areas of widely spaced whitebark pine burned despite their location on

Figure 31—Downed woody fuels in timberline stands are ordinarily light and fires are generally restricted to small groups of trees. The greatest fire hazard is posed by severe fires invading from lower, more productive forests.

depauperate scree slopes with little or no ground fuel between individual trees. The available fuel was restricted to litter deposited beneath or slightly downhill from the crown shadow. Lower portions of whitebark pine stands were ignited by crown fire encroaching from downslope. Trees were consumed in the upper reaches of the stands by a combination of ignited litter at their bases and by exposure to intense radiant heat from downslope. Trees lacking accumulated litter did not burn.

Role of Fire

Fire is relatively infrequent in much of the high country. Many stands may have substantial snowpacks, which may last through the summer months. Grasses and forbs cure in August or September, about the time that late summer storms often begin, effectively ending the fire season. Thus, though the incidence of lightning strikes may be relatively high, stand-replacing fires are rare. In Montana, Gabriel (1976) concluded that the fire history at high elevations in the Bob Marshall Wilderness was one of lightning strikes igniting many fires that burned small areas, from individual trees to several acres. Patchy distribution of trees, variable topography and exposures, and frequent expanses of rock or fell fields limit the extent of fire. Billings (1969) studied fire in the high-elevation "ribbon forests" of the Medicine Bow Mountains in southern Wyoming, where ribbons of trees alternate with expanses of moist meadow vegetation. Fires appeared to be relatively common, but local in extent. There appeared to be little cross-correlation between fires occurring in neighboring patches of trees. Intervening snowglade meadows or tundra restricted fire spread. Fires in these ribbon forests may be ground or crown, with krummholz patches almost always experiencing crown fires because of the trees' short stature. Succession after ground fires may return the stand to its prefire condition in relatively few years. After crown fires, the site is no longer ameliorated by the presence of trees, and a return to the forested state may be extremely slow. Slow regeneration adds to the difficulty in determining fire intervals, since relatively old burns may support only sparse or otherwise underdeveloped stands. Estimates of fire-free intervals range from 50 to 300 years (Arno 1986,

1989; Heinselmann 1981). Fire has its greatest impact when occasional large high-intensity fires invade from lower elevation forests during severe fire conditions. Periods of high wind and low fuel moistures present the greatest fire hazard.

Fire retains seral species, creates a mosaic of stand ages and species composition, and opens dense stands, thus increasing undergrowth productivity. Retention of whitebark pine in subalpine forests depends on periodic fires that remove more tolerant conifers and create openings where regeneration is more successful. Whitebark pine regeneration is facilitated by Clark's nutcracker. Nutcrackers collect the heavy wingless pine seeds and cache them in the soil. They often use burned areas as caching sites (Arno and Hoff 1989; Lanner and Vander Wall 1980). Most whitebark pine germinants probably originate from forgotten nutcracker caches.

Forest Succession

Seral species in Fire Group Eight stands may include lodgepole pine, whitebark pine, Engelmann spruce, and subalpine fir. Figure 32 illustrates the hypothetical role of fire in the group. Subsequent letters in this section refer to figure 32.

Secondary succession begins with a mixture of herbs and shrubs (A). Adverse conditions for conifer regeneration may allow this vegetation to dominate the stand for an extended period. Physical disruption of the stand by snow and wind, rock slides, and talus slippage are more common recyclers of high, unproductive sites than fire. Lodgepole pine may seed in on disturbed soil, and more sun-sensitive spruce and subalpine fir may establish in the shelter of snags, logs, or shrubs. Whitebark pine typically germinates from seed cached by Clark's nutcracker (B). One hundred years or more may pass before conifers dominate the site. It may take another 100 years before a mature forest develops (C). Even after a century, most stands retain an open character. Stand and fuel conditions will probably not support a fire of any consequence during this time. It may take two or three centuries to reach climax status (D). Eventually, stands will break up under the impact of snow and wind damage, insect and disease mortality, windthrow and senescence, creating more woody fuels. Where spruce or subalpine fir are the only available seral and climax species, low fires at all stages change the age structure rather than the species composition. Where whitebark pine or lodgepole pine are seral, fire favors them over the less fire-resistant conifers. Sparse fuels and unfavorable weather conditions limit the occurrence of moderate fires at any stage. Severe, stand-destroying fires become a possibility in mature or climax stands

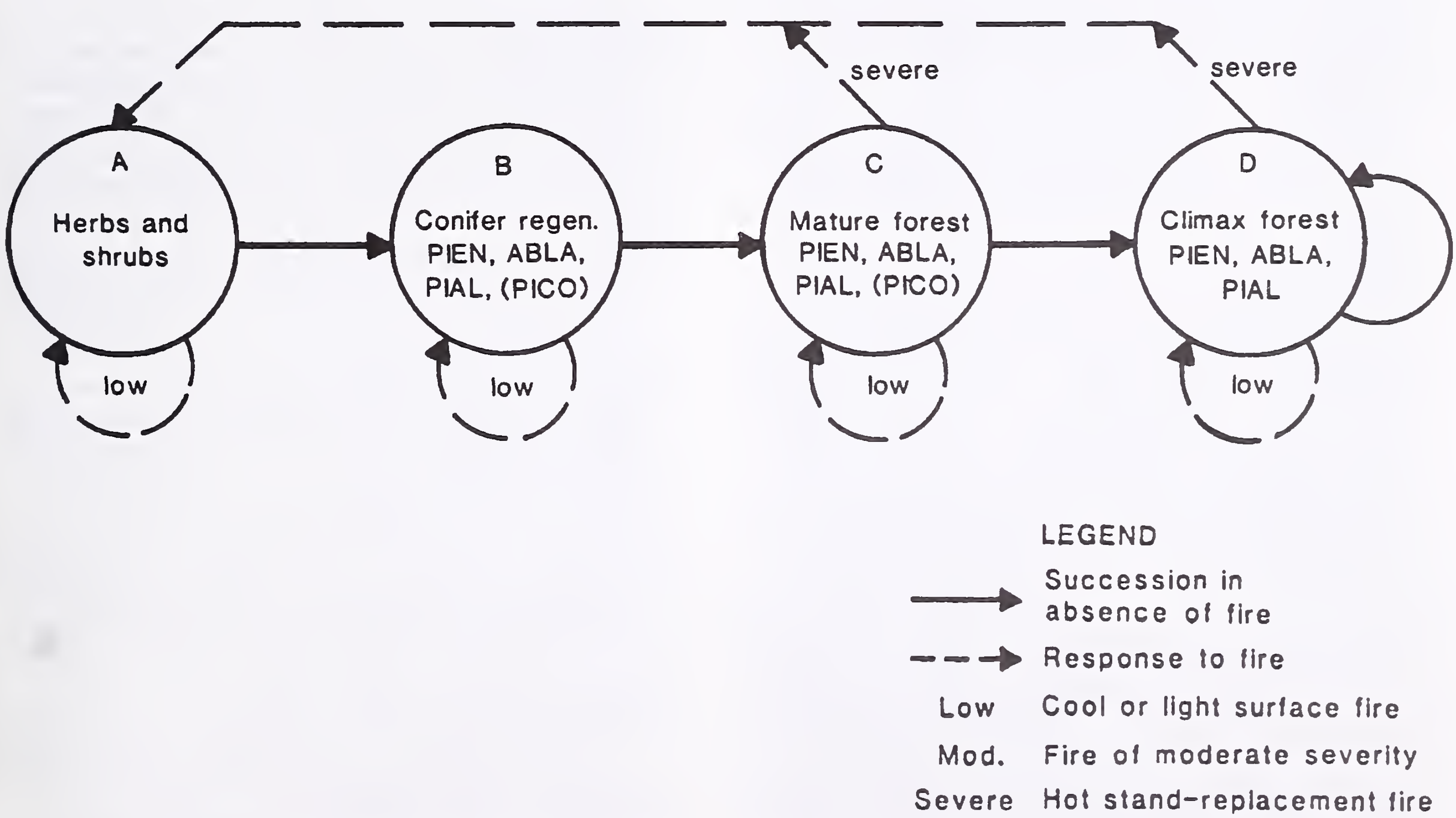

Figure 32—Hypothetical fire-related successional pathways for Fire Group Eight habitat types.

only during periods of drought. Severe fires will recycle the stand to the herbaceous state (A).

In high-elevation burns in Colorado and Wyoming, Stahelin (1943) found that the most important factors affecting rate of regeneration were seed tree, abundance, soil, exposure, and ground cover. Stocking seemed to be favored on north-facing slopes, lighter gravelly soils, well-scattered seed trees, and little or no graminoid cover. On these sites, 10 or more seed trees/acre were considered to be adequate to restock the site within 50 years.

Fire Management Considerations

Timber production is rarely an important management objective in Fire Group Eight forests. Watershed, wildlife, and recreation are often the dominant values. Consumptive uses may be restricted by natural area or wilderness designation. Fire is infrequent, and when it does occur damage in terms of management is usually slight. These sites are fragile, however, and can easily be damaged by mechanized firefighting equipment. For Fire Group Eight habitat types, the primary consideration should be the development of prescriptions that allow fire to more nearly play its natural role (Fischer 1984).

In general, past policies of fire suppression have probably affected high-elevation subalpine stands less than other habitat types because of their relatively long fire-free intervals. Because of their susceptibility to fires originating at lower elevations, however, they can be affected by excessive fuel buildups in lower, more fire-prone forests. Fire management should take into consideration this relationship.

Although of little interest for commercial timber, whitebark pine is an important food source for grizzly and black bears, red squirrels, and Clark's nutcrackers. In some areas grizzly bears may be dependent on whitebark pine seed stored in large cone caches by red squirrels. The nutritious seeds become available in the fall shortly before denning season. Bears apparently prefer mixed stands of pine, spruce, and fir. These stands support stable populations of squirrels, which in turn increase the available cone caches. In recent decades, many populations of whitebark pine have succumbed to the combined effects of fire suppression and mountain pine beetle (*Dendroctonus ponderosae*) attack. Whitebark pine cannot ordinarily outcompete more tolerant conifers on moist sites. Longer fire-free intervals increase pine susceptibility to beetle attack and accelerate conversion to spruce or subalpine fir. Prescribed natural fires can help maintain more favorable conditions for regeneration of whitebark pine. Because whitebark pine grows slowly, active management, including prescribed fire application, may be necessary now to perpetuate whitebark pine and its dependent wildlife species in the future (Arno 1986).

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APPENDIX A: EASTERN IDAHO-WESTERN WYOMING FOREST HABITAT TYPES AND PHASES AND ASSIGNED ADP CODES

(Source: Steele and others 1983; Mueggler 1988)

ADP code[1]	Abbreviation	Habitat types and phases: Scientific name	Habitat types and phases: Common name
000		***Pinus flexilis* Series**	
080	PIFL/HEKI h.t.	*Pinus flexilis/Hesperochloa kingii* h.t.	limber pine/spike fescue
050	PIFL/FEID h.t.	*Pinus flexilis/Festuca idahoensis* h.t.	limber pine/Idaho fescue
051	-FEID phase	-*Festuca idahoensis* phase	-Idaho fescue phase
060	PIFL/CELE h.t.	*Pinus flexilis/Cercocarpus ledifolius* h.t.	limber pine/curl-leaf mountain mahogany
070	PIFL/JUCO h.t.	*Pinus flexilis/Juniperus communis* h.t.	limber pine/common juniper
200		***Pseudotsuga menziesii* Series**	
220	PSME/FEID h.t.	*Pseudotsuga menziesii/Festuca idahoensis* h.t.[2]	Douglas-fir/Idaho fescue
221	-FEID phase	-*Festuca idahoensis* phase[2]	-Idaho fescue phase
380	PSME/SYOR h.t.	*Pseudotsuga menziesii/Symphoricarpos oreophilus* h.t.	Douglas-fir/mountain snowberry
370	PSME/ARCO h.t.	*Pseudotsuga menziesii/Arnica cordifolia* h.t.	Douglas-fir/heartleaf arnica
371	-ARCO phase	-*Arnica cordifolia* phase	-heartleaf arnica phase
372	-ASMI phase	-*Astragalus miser* phase	-weedy milkvetch phase
385	PSME/CELE h.t.	*Pseudotsuga menziesii/Cercocarpus ledifolius* h.t.	Douglas-fir/curl-leaf mountain-mahogany
360	PSME/JUCO h.t.	*Pseudotsuga menziesii/Juniperus communis* h.t.	Douglas-fir/common juniper
395	PSME/BERE h.t.	*Pseudotsuga menziesii/Berberis repens* h.t.	Douglas-fir/Oregon grape
397	-SYOR phase	-*Symphoricarpos oreophilus* phase	-mountain snowberry phase
399	-JUCO phase	-*Juniperus communis* phase	-common juniper phase
398	-CAGE phase	-*Carex geyeri* phase[2]	-elk sedge phase
396	-BERE phase	-*Berberis repens* phase	-Oregon grape phase
320	PSME/CARU h.t.	*Pseudotsuga menziesii/Calamagrostis rubescens* h.t.	Douglas-fir/pinegrass
325	-PAMY	-*Pachistima myrsinites* phase	-pachistima phase
323	-CARU phase	-*Calamagrostis rubescens* phase	-pinegrass phase
340	PSME/SPBE h.t.	*Pseudotsuga menziesii/Spiraea betulifolia* h.t.	Douglas-fir/white spirea
343	-CARU	-*Calamagrostis rubescens* phase	-pinegrass phase
341	-SPBE phase	-*Spiraea betulifolia* phase	-white spirea phase
375	PSME/OSCH h.t.	*Pseudotsuga menziesii/Osmorhiza chilensis* h.t.	Douglas-fir/mountain sweetroot
310	PSME/SYAL h.t.	*Pseudotsuga menziesii/Symphoricarpos albus* h.t.	Douglas-fir/common snowberry
313	-SYAL phase	-*Symphoricarpos albus* phase	-common snowberry phase
270	PSME/PHMO h.t.	*Pseudotsuga menziesii/Physocarpus monogynus* h.t.[2]	Douglas-fir/mountain ninebark
280	PSME/VAGL h.t.	*Pseudotsuga menziesii/Vaccinium globulare* h.t.	Douglas-fir/huckleberry
281	-VAGL phase	-*Vaccinium globulare* phase	-blue huckleberry phase
390	PSME/ACGL h.t.	*Pseudotsuga menziesii/Acer glabrum* h.t.	Douglas-fir/mountain maple
391	-PAMY phase	-*Pachistima myrsinites* phase	-pachistima phase
260	PSME/PHMA h.t.	*Pseudotsuga menziesii/Physocarpus malvaceus* h.t.	Douglas-fir/ninebark
266	-PAMY phase	-*Pachistima myrsinites* phase	-pachistima phase
265	-PSME phase	-*Pseudotsuga menziesii* phase	-Douglas-fir phase
400		***Picea engelmannii* Series**	
493	PIEN/HYRE h.t.	*Picea engelmannii/Hypnum revolutum* h.t.	spruce/hypnum
495	PIEN/ARCO h.t.	*Picea engelmannii/Arnica cordifolia* h.t.	spruce/heartleaf arnica
497	PIEN/RIMO h.t.	*Picea engelmannii/Ribes montigenum* h.t.	spruce/mountain gooseberry
475	PIEN/JUCO h.t.	*Picea engelmannii/Juniperus communis* h.t.	spruce/common juniper
485	PIEN/VASC h.t.	*Picea engelmannii/Vaccinium scoparium* h.t.	spruce/grouse whortleberry
470	PIEN/LIBO h.t.	*Picea engelmannii/Linnaea borealis* h.t.	spruce/twinflower
440	PIEN/GATR h.t.	*Picea engelmannii/Galium triflorum* h.t.	spruce/sweet-scented bedstraw
430	PIEN/PHMA h.t.	*Picea engelmannii/Physocarpus malvaceus* h.t.[2]	spruce/ninebark
490	PIEN/CADI h.t.	*Picea engelmannii/Carex disperma* h.t.	spruce/soft-leaved sedge
415	PIEN/CALE h.t.	*Picea engelmannii/Caltha leptosepala* h.t.	spruce/elkslip marsh marigold
410	PIEN/EQAR h.t.	*Picea engelmannii/Equisetum arvensis* h.t.	spruce/common horsetail

(con.)

APPENDIX A (Con.)

ADP code[1]	Abbreviation	Habitat types and phases: Scientific name	Common name
600		***Abies lasiocarpa*** **Series**	
650	ABLA/CACA h.t.	*Abies lasiocarpa/Calamagrostis canadensis* h.t.	subalpine fir/bluejoint
655	-LEGL phase	-*Ledum glandulosum* phase[2]	-Labrador tea phase
654	-VACA phase	-*Vaccinium caespitosum* phase[2]	-dwarf huckleberry phase
651	-CACA phase	-*Calamagrostis canadensis* phase	-bluejoint phase
635	ABLA/STAM h.t.	*Abies lasiocarpa/Streptopus amplexifolius* h.t.[2]	subalpine fir/twisted stalk
636	-STAM phase	-*Streptopus amplexifolius* phase[2]	-twisted stalk phase
670	ABLA/MEFE h.t.	*Abies lasiocarpa/Menziesia ferruginea* h.t.[2]	subalpine fir/menziesia
671	-MEFE phase	-*Menziesia ferruginea* phase	-menziesia phase
601	ABLA/ACRU h.t.	*Abies lasiocarpa/Actaea rubra* h.t.	subalpine fir/baneberry
603	ABLA/PHMA h.t.	*Abies lasiocarpa/Physocarpus malvaceus* h.t.	subalpine fir/ninebark
645	ABLA/ACGL h.t.	*Abies lasiocarpa/Acer glabrum* h.t.	subalpine fir/mountain maple
647	-PAMY phase	-*Pachistima myrsinites* phase	-pachistima phase
660	ABLA/LIBO h.t.	*Abies lasiocarpa/Linnaea borealis* h.t.	subalpine fir/twinflower
663	-VASC phase	-*Vaccinium scoparium* phase	-grouse whortleberry phase
661	-LIBO phase	-*Linnaea borealis* phase	-twinflower phase
690	ABLA/XETE h.t.	*Abies lasiocarpa/Xerophyllum tenax* h.t.[2]	subalpine fir/beargrass
691	-VAGL phase	-*Vaccinium globulare* phase[2]	-blue huckleberry phase
692	-VASC phase	-*Vaccinium scoparium* phase[2]	-grouse whortleberry phase
720	ABLA/VAGL h.t.	*Abies lasiocarpa/Vaccinium globulare* h.t.	subalpine fir/blue huckleberry
721	-VASC phase	-*Vaccinium scoparium* phase	-grouse whortleberry phase
722	-PAMY phase	-*Pachistima myrsinites* phase	-pachistima phase
723	VAGL phase	-*Vaccinium globulare* phase	-blue huckleberry phase
830	ABLA/LUHI h.t.	*Abies lasiocarpa/Luzula hitchcockii* h.t.[2]	subalpine fir/smooth woodrush
831	-VASC phase	-*Vaccinium scoparium* phase[2]	-grouse whortleberry phase
730	ABLA/VASC h.t.	*Abies lasiocarpa/Vaccinium scoparium* h.t.	subalpine fir/grouse whortleberry
731	-CARU phase	-*Calamagrostis rubescens* phase	-pinegrass phase
734	-PIAL phase	-*Pinus albicaulis* phase	-whitebark pine phase
732	-VASC phase	-*Vaccinium scoparium* phase	-grouse whortleberry phase
701	ABLA/ARLA h.t.	*Abies lasiocarpa/Arnica latifolia* h.t.	subalpine fir/mountain arnica
607	ABLA/SYAL h.t.	*Abies lasiocarpa/Symphoricarpos albus* h.t.	subalpine fir/common snowberry
609	ABLA/THOC h.t.	*Abies lasiocarpa/Thalictrum occidentale* h.t.	subalpine fir/western meadowrue
760	ABLA/OSCH h.t.	*Abies lasiocarpa/Osmorhiza chilensis* h.t.	subalpine fir/mountain sweetroot
761	-PAMY phase	-*Pachistima myrsinites* phase	-pachistima phase
762	-OSCH phase	-*Osmorhiza chilensis* phase	-mountain sweetroot phase
705	ABLA/SPBE h.t.	*Abies lasiocarpa/Spiraea betulifolia* h.t.	subalpine fir/white spirea
750	ABLA/CARU h.t.	*Abies lasiocarpa/Calamagrostis rubescens* h.t.	subalpine fir/pinegrass
752	-PAMY phase	-*Pachistima myrsinites* phase	-pachistima phase
751	-CARU phase	-*Calamagrostis rubescens* phase	-pinegrass phase
703	ABLA/BERE h.t.	*Abies lasiocarpa/Berberis repens* h.t.	subalpine fir/Oregon grape
704	-CAGE phase	-*Carex geyeri* phase[2]	-elk sedge phase
702	-BERE phase	-*Berberis repens* phase	-Oregon grape phase
790	ABLA/CAGE h.t.	*Abies lasiocarpa/Carex geyeri* h.t.[2]	subalpine fir/elk sedge
791	-CAGE phase	-*Carex geyeri* phase[2]	-elk sedge phase
745	ABLA/JUCO h.t.	*Abies lasiocarpa/Juniperus communis* h.t.	subalpine fir/common juniper
810	ABLA/RIMO h.t.	*Abies lasiocarpa/Ribes montigenum* h.t.	subalpine fir/mountain gooseberry
812	-PIAL phase	-*Pinus albicaulis* phase	-whitebark pine phase
811	-RIMO phase	-*Ribes montigenum* phase	-mountain gooseberry phase
707	ABLA/PERA h.t.	*Abies lasiocarpa/Pedicularis racemosa* h.t.	subalpine fir/pedicularis
780	ABLA/ARCO h.t.	*Abies lasiocarpa/Arnica cordifolia* h.t.	subalpine fir/heartleaf arnica
784	-PIEN phase	-*Picea engelmannii* phase	-Engelmann spruce phase
783	-SHCA phase	-*Shepherdia canadensis* phase	-russett buffalo-berry phase
782	-ASMI phase	-*Astragalus miser* phase	-weedy milkvetch phase
781	-ARCO phase	-*Arnica cordifolia* phase	-heartleaf arnica phase
795	ABLA/CARO h.t.	*Abies lasiocarpa/Carex rossii* h.t.	subalpine fir/Ross sedge

(con.)

APPENDIX A (Con.)

ADP code[1]	Abbreviation	Habitat types and phases: Scientific name	Habitat types and phases: Common name
870		***Pinus albicaulis* Series**	
875	PIAL/VASC h.t.	*Pinus albicaulis/Vaccinium scoparium* h.t.	whitebark pine/grouse whortleberry
880	PIAL/CAGE h.t.	*Pinus albicaulis/Carex geyeri* h.t.	whitebark pine/elk sedge
885	PIAL/JUCO h.t.	*Pinus albicaulis/Juniperus communis* h.t.	whitebark pine/common juniper
886	-SHCA phase	-*Shepherdia canadensis* phase	-russett buffalo-berry phase
887	-JUCO phase	-*Juniperus communis* phase	-common juniper phase
895	PIAL/CARO h.t.	*Pinus albicaulis/Carex rossii* h.t.	whitebark pine/Ross sedge
896	-PICO phase	-*Pinus contorta* phase	-lodgepole pine phase
897	-CARO phase	-*Carex rossii* phase	-Ross sedge phase
891	PIAL/FEID h.t.	*Pinus albicaulis/Festuca idahoensis* h.t.	whitebark pine/Idaho fescue
900		***Pinus contorta* Series**	
930	PICO/LIBO h.t.	*Pinus contorta/Linnaea borealis* c.t.[2]	lodgepole pine/twinflower
935	PICO/VAGL c.t.	*Pinus contorta/Vaccinium globulare* c.t.[2]	lodgepole pine/blue huckleberry
940	PICO/VASC c.t.	*Pinus contorta/Vaccinium scoparium* c.t.[2]	lodgepole pine/grouse whortleberry
945	PICO/SPBE c.t.	*Pinus contorta/Spiraea betulifolia* c.t.[2]	lodgepole pine/white spirea
950	PICO.CARU c.t.	*Pinus contorta/Calamagrostis rubescens* c.t.[2]	lodgepole pine/pinegrass
955	PICO/CAGE c.t.	*Pinus contorta/Carex geyeri* c.t.[2]	lodgepole pine/elk sedge
960	PICO/JUCO c.t.	*Pinus contorta/Juniperus communis* c.t.[2]	lodgepole pine/common juniper
975	PICO/SHCA c.t.	*Pinus contorta/Shepherdia canadensis* c.t.[2]	lodgepole pine/russett buffalo-berry
965	PICO/ARCO c.t.	*Pinus contorta/Arnica cordifolia* c.t.[2]	lodgepole pine/heartleaf arnica
970	PICO/CARO c.t.	*Pinus contorta/Carex rossii* c.t.[2]	lodgepole pine/Ross sedge
990		***Populus tremuloides* Series**	
	POTR/AMAL-SYOR /CARU c.t.	*Populus tremuloides/Amelanchier alnifolia -Symphoricarpos oreophilus/Calamagrostis rubescens* c.t.	aspen/serviceberry-mountain snowberry/pinegrass
	POTR/AMAL-SYOR /TALL FORB c.t.	*Populus tremuloides/Amelanchier alnifolia -Symphoricarpos oreophilus*/Tall Forb c.t.	aspen/serviceberry-mountain snowberry/tall forb
	POTR/AMAL /TALL FORB	*Populus tremuloides/Amelanchier alnifolia* /Tall Forb c.t.	aspen/serviceberry/tall forb
	POTR/AMAL /THFE c.t.	*Populus tremuloides/Amelanchier alnifolia /Thalictrum fendleri* c.t.	aspen/serviceberry/Fendler's meadowrue
	POTR/ARTR c.t.	*Populus tremuloides/Artemisia tridentata* c.t.	aspen/big sagebrush
	POTR/ASMI c.t.	*Populus tremuloides/Astragalus miser* c.t.	aspen/weedy milkvetch
	POTR/BRCA c.t	*Populus tremuloides/Bromus carinatus* c.t.	aspen/California brome
	POTR/CARO c.t.	*Populus tremuloides/Carex rossii* c.t.	aspen/Ross sedge
	POTR/EQAR c.t.	*Populus tremuloides/Equisetum arvense* c.t.	aspen/common horsetail
	POTR/POPR c.t.	*Populus tremuloides/Poa pratensis* c.t.	aspen/Kentucky bluegrass
	POTR/SHCA c.t.	*Populus tremuloides/Shepherdia canadensis* c.t.	aspen/russet buffaloberry
	POTR/SYOR /CARU c.t.	*Populus tremuloides/Symphoricarpos oreophilus /Calamagrostis rubescens* c.t.	aspen/mountain snowberry/pinegrass
	POTR/SYOR /THFE c.t.	*Populus tremuloides/Symphoricarpos oreophilus /Thalictrum fendleri* c.t.	aspen/mountain snowberry/Fendler's meadowrue
	POTR/SYOR TALL FORB c.t.	*Populus tremuloides/Symphoricarpos oreophilus* /Tall Forb c.t.	aspen/mountain snowberry/tall forb
	POTR/TALL FORB c.t.	*Populus tremuloides*/Tall Forb c.t.	aspen/tall forb
	POTR/THFE c.t.	*Populus tremuloides/Thalictrum fendleri* c.t.	aspen/Fendler's meadowrue
	POTR/WYAM c.t.	*Populus tremuloides/Wyethia amplexicaulis* c.t.	aspen/northern mule's-ears
	POTR-ABLA/ AMAL c.t.	*Populus tremuloides-Abies lasiocarpa /Amalanchier alnifolia* c.t.	aspen-subalpine fir/serviceberry

(con.)

APPENDIX A (Con.)

ADP code[1]	Abbreviation	Habitat types and phases: Scientific name	Common name
	POTR-ABLA. /PERA c.t.	*Populus tremuloides-Abies lasiocarpa /Pedicularis racemosa* c.t.	aspen-subalpine fir/pedicularis
	POTR-ABLA /SHCA c.t.	*Populus tremuloides-Abies lasiocarpa /Shepherdia canadensis* c.t.	aspen-subalpine fir/russet buffaloberry
	POTR-ABLA /TALL FORB c.t.	*Populus tremuloides-Abies lasiocarpa* /Tall Forb c.t.	aspen-subalpine fir/tall forb
	POTR-ABLA /SYOR c.t.	*Populus tremuloides-Abies lasiocarpa /Symphoricarpos oreophilus* c.t.	aspen-subalpine fir/mountain snowberry
	POTR-ABLA /SYOR/THFE c.t.	*Populus tremuloides-Abies lasiocarpa /Symphoricarpos oreophlis/Thalictrum fendleri* c.t.	aspen-subalpine fir/mountain snowberry/Fendler's meadowrue
	POTR-PICO /CAGE c.t.	*Populus tremuloides-Pinus contorta /Carex geyeri* c.t.	aspen-lodgepole pine/elksedge
	POTR-PICO /SYOR c.t.	*Populus tremuloides-Pinus contorta /Symphoricarpos oreophilus* c.t.	aspen-lodgepole pine/mountain snowberry
	POTR-PSME /AMAL c.t.	*Populus tremuloides-Pseudotsuga menziesii /Amelanchier alnifolia* c.t.	aspen-Douglas-fir/serviceberry
	POTR-PSME /CARU c.t.	*Populus tremuloides-Pseudotsuga menziesii /Calamagrostis rubescens* c.t.	aspen-Douglas-fir/pinegrass
	POTR-PSME /SYOR c.t.	*Populus tremuloides-Pseudotsuga menziesii /Symphoricarpos oreophilus* c.t.	aspen-Douglas-fir/mountain snowberry

Total number of habitat types = 58[3]
Total number of habitat types and additional phases = 82[4]
Total number of *Pinus contorta* community types = 10

[1]Automatic data processing codes.
[2]Incidental habitat types or phases, or *Pinus contorta* community types omitted from other charts and tables.
[3]Eight of these are incidental to the study area.
[4]Five of the additional phases are incidental to the study area.

APPENDIX B: SCIENTIFIC AND COMMON NAMES OF PLANTS APPEARING IN TEXT

Common name	Scientific name	Common synonym
Trees		
Aspen	*Populus tremuloides*	quaking/trembling aspen
Big sagebrush	*Artemisia tridentata*	
Black elderberry	*Sambucus racemosa*	red elderberry
Blue spruce	*Picea pungens*	
Common chokecherry	*Prunus virginiana*	
Common juniper	*Juniperus communis*	
Curlleaf mountain-mahogany	*Cercocarpus ledifolius*	curlleaf cercocarpus
Douglas-fir	*Pseudotsuga menziesii*	
Engelmann spruce	*Picea engelmannii*	
Limber pine	*Pinus flexilis*	
Lodgepole pine	*Pinus contorta* (v. *latifolia*)	Rocky Mountain lodgepole
Mountain ash	*Sorbus scopulina*	
Red-oiser dogwood	*Cornus stolonifera*	*Cornus sericea*
Rocky Mountain juniper	*Juniperus scopulorum*	
Rocky Mountain maple	*Acer glabrum*	mountain maple
Saskatoon serviceberry	*Amelanchier alnifolia*	serviceberry
Scouler willow	*Salix scouleriana*	
Sitka alder	*Alnus sinuata*	A. *virdis* ssp. *sinuata*
Subalpine fir	*Abies lasiocarpa*	alpine fir
Whitebark pine	*Pinus albicaulis*	

Shrubs, Grasses, and Forbs

Scientific name	Common name	Common synonym
Shrubs		
Acer glabrum	Rocky Mountain maple	mountain maple
Amelanchier alnifolia	western serviceberry	serviceberry, Saskatoon
Arctostaphylos uva-ursi	kinnikinnick	bearberry
Artemisia tridentata	big sagebrush	
Berberis repens	creeping Oregongrape	*Mahonia repens* Oregon grape
Ceanothus velutinus	snowbush ceanothus	
Cercocarpus ledifolius	curlleaf mountain-mahogany	
Clematis columbiana	Columbia virgins-bower	
Cornus canadensis	bunchberry	
Cornus stolonifera	red-oiser dogwood	*Cornus sericea*
Holodiscus discolor	creambush ocean-spray	
Juniperus communis	common juniper	
Juniperus horizontalis	creeping juniper	
Kalmia polifolia	western swamp kalmia	
Ledum glandulosum	Labrador-tea	
innaea borealis	twinflower	
Lonicera involucrata	black twin-berry honeysuckle	
Lonicera utahensis	Utah honeysuckle	
Menziesia ferruginea	rusty menziesia	menziesia
Pachistima myrsinites	mountain lover	pachistima; pachystima
Physocarpus malvaceous	mallow ninebark	ninebark
Physocarpus monogynus	mountain ninebark	
Phyllodoce empetriformis	pink mountain-heather	
Potentilla fruticosa	shrubby cinquefoil	
Prunus virginiana	common chokecherry	
Purshia tridentata	antelope bitterbrush	

(con.)

Scientific name	Common name	Common synonym
Ribes cereum	wax currant	
Ribes lacustre	prickly currant	
Ribes montigenum	alpine prickly currant	mountain gooseberry
Ribes viscossimum	sticky currant	
Rosa gymnocarpa	baldhip rose	
Rosa woodsii	Wood's rose	
Rubus parviflorus	thimbleberry	
Salix scouleriana	Scouler willow	
Sambucus racemosa	black (or red) elderberry	*S. racemosa* ssp. *pubens*
Shepherdia canadensis	russet buffaloberry	
Sorbus scopulina	mountain ash	
Spiraea betulifolia	shiny-leaf spirea	white spirea
Symphoricarpos albus	common snowberry	
Symphoricarpos oreophilus	mountain snowberry	
Vaccinium caespitosum	dwarf huckleberry	
Vaccinium globulare	globe huckleberry	blue huckleberry
Vaccinium occidentale	western huckleberry	
Vaccinium scoparium	whortleberry	grouse whortleberry
GRASSES:		
Agropyron cristatum	crested wheatgrass	
Bromus carinatus	California brome	
Bromus ciliatus	fringed brome	
Calamagrostis canadensis	bluejoint reedgrass	bluejoint
Calamagrostis rubescens	pinegrass	
Carex disperma	soft leaved sedge	
Carex geyeri	elk sedge	
Carex rossii	Ross sedge	
Deschampsia cespitosa	tufted hairgrass	
Elymus caninus	bearded wheatgrass	*Agropyron cainium*
Elymus glaucus	blue wildrye	*E. virescens*
Elymus trachycaulus ssp. *trachycaulus*	slender wheatgrass	*Agropyron trachycaulum*
Festuca idahoensis	Idaho fescue	
Festuca thurberi	Thurber fescue	
Glyceria elata	fowl mannagrass	
Hesperochloa kingii	spike-fescue	*Leucopoa kingii*
Koeleria cristata	prairie junegrass	*K. macrantha*
Leymus cinereus	Giant wildrye	*Elymus cinereus*
Luzula hitchcockii	smooth woodrush	
Melica bulbosa	oniongrass	
Poa nervosa	Wheeler's bluegrass	
Poa pratensis	Kentucky bluegrass	
Pseudoroegneria spicata	bluebunch wheatgrass	*Agropyron spicatum*
Stipa occidentalis	western needlegrass	
Thinopyrum intermedium ssp. *intermedium*	intermediate wheatgrass	*Agropyron intermedium*
FORBS:		
Achillea millefolium	common yarrow	
Actaea rubra	baneberry	
Agastache urticifolia	nettle-leaf horsemint	
Antennaria microphylla	rosy pussytoes	
Antennaria racemosa	raceme pussy-toes	
Aquilegia coerulea	Colorado columbine	
Arnica cordifolia	heart-leaf arnica	

(con.)

APPENDIX B (Con.)

Scientific name	Common name	Common synonym
Arnica latifolia	broadleaf arnica	mountain arnica
Aster conspicuus	showy aster	
Aster engelmannii	Engelmann aster	
Astragalus miser	weedy milkvetch	timber milkvetch
Balsamorhiza macrophylla	large-leaved balsamroot	
Balsamorhiza sagittata	arrowleaf balsamroot	
Caltha leptosepala	elkslip marshmarigold	
Campanula rotundifolia	Scotch bellflower	
Corallorhiza maculata	spotted coral-root	
Creptis acuminata	tapertip hawksbeard	
Cymopterus hendersonii	Henderson's cymopterus	
Delphinium spp.	delphinium	
Descurania richardsonii	mountain tansymustard	
Disporum trachycarpum	wartberry fairy-bell	
Dracocephalum parviflorum	American dragonhead	
Epilobium angustifolium	fireweed	
Equisetum arvense	field horsetail	common horsetail
Erigeron peregrinus	wandering fleabane	
Fragaria vesca	woods strawberry	
Fragaria virginiana	wild strawberry	
Frasera speciosa	giant frasera	
Galium triflorum	sweetscented bedstraw	
Geranium richardsonii	white geranium	
Geranium viscosissimum	sticky purple geranium	
Goodyera oblongifolia	western rattlesnake plantain	
Hedysarum boreale	northern hehysarum	
Hieracium albiflorum	white-flowered hawkweed	
Hypnum revolutum	hypnum	
Lathyrus lanzwertii	thickleaved peavine	
Ligusticum filicinum	fern-leaf licorice-root	
Linum perenne	blue flax	
Lupinus argenteus	silvery lupine	
Mertensia ciliata	broad-leaf bluebells	
Osmorhiza chilensis	mountain sweet-root	mountain sweet-cicely
Osmorhiza depauperata	blunt-fruit sweet-root	blunt-fruit sweet-cicely
Pedicularis bracteosa	bracted lousewort	
Pedicularis racemosa	sickletop lousewort	pedicularis
Perideridia gairdneri	Gairdner's yampah	
Potentilla gracilis	beauty cinquefoil	
Pyrola asarifolia	alpine pyrola	
Pyrola chlorantha	green pyrola	
Pyrola secunda	sidebells pyrola	
Rudbeckia occidentalis	black head	
Saxifraga arguta	brook saxifrage	
Senecio streptanthifolius	cleft-leaf groundsel	
Senecia triangularis	arrowleaf groundsel	
Silene menziesii	Menzies' silene	
Smilacina racemosa	false spikenard	
Smilacina stellata	starry solomon-plume	
Solidago multiradiata	northern goldenrod	
Streptopus amplexifolius	clasping-leaved twistedstalk	twisted stalk
Thalictrum fendleri	Fendler's meadowrue	
Thalictrim occidentale	western meadowrue	
Trollius laxus	globeflower	
Valeriana occidentalis	western valerian	
Vica americana	American vetch	
Viqueria multiflora	viqueria	
Viola adunca	hook violet	
Wyethia amplexicaulis	northern mule's-ears	
Xerophyllum tenax	beargrass	

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Bradley, Anne F.; Fischer, William C.; Noste, Nonan V. 1992. Fire ecology of the forest habitat types of eastern Idaho and western Wyoming. Gen. Tech. Rep. INT-290. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 92 p.

Provides information on fire as an ecological factor in the forest habitat types occurring in eastern Idaho and western Wyoming. Identifies Fire Groups based on fire's role in forest succession. Describes forest fuels and suggests considerations for fire management.

KEYWORDS: fire effects, forest ecology, forest succession, forest fire, fire management, forest fuels

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

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